National Aeronautics and Space Administration

NASA @ SC10

November 13–19, 2010 • New Orleans • Booth #3839

Welcome to NASA at SC10

Greetings SC10 Participants:

As the world's supercomputing community gathers in New Orleans to celebrate the latest breakthroughs in high-performance computing—along with this resilient city's rich history and culture—it is my pleasure to invite you to visit NASA at Booth #3839 on the SC10 conference floor. At our exhibit, you'll learn first-hand how Agency supercomputers are enabling key advances in aviation safety and efficiency, exploration of the universe, design of next-generation space vehicles, and the understanding of our home planet.

It is especially fitting that one of the themes of this year's conference is climate simulation. Since Hurricane Katrina in 2005, NASA researchers have developed remarkable, high-resolution simulations of this devastating storm's track, intensity, and near-eye wind distributions. When visiting our exhibit, you will see how these simulations, augmented by amazing visualizations, are now providing insight into global tropical storm formation and development that could ultimately save lives and reduce property damage around the globe.

You will also hear how high-fidelity aeronautics simulations, aimed at reducing aircraft landing-gear noise, will contribute to improving the sonic environment near metropolitan airports. At the same time, our scientists are continuing the challenging work of predicting and analyzing potential and actual sources of debris that pose risk to remaining Space Shuttle missions during launch and in orbit. And, as the Agency charts a new course for space exploration, its high-end computers are facilitating the design and development of heavy-lift and multipurpose crew vehicles that will take astronauts beyond low-Earth orbit.

While at SC10, I hope you take advantage of the opportunity to meet some of the talented and dedicated men and women of NASA, whose work continues to benefit America and the world.

Charles Bolden
NASA Administrator

NASA @ SC10

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Computational Scaling for an Unstructured-Grid CFD Solver

Aeronautics Research Mission Directorate

FUN3D is a suite of unstructured-grid computational fluid dynamics (CFD) codes used for a broad spectrum of aerodynamic analysis and aeronautic design challenges supporting NASA missions. FUN3D utilizes an adjoint-based technique for design optimization, error estimation, and mesh adaptation. To enable these computationally demanding adjoint-based strategies for 3D simulations of complex flowfields, FUN3D must take full advantage of massively parallel computing environments. This project seeks to evaluate and improve application performance for FUN3D simulations running on many thousands of processor cores.

Using NASA's powerful supercomputers, we have demonstrated that complex FUN3D simulations can be run effectively on large numbers of processors. To mitigate performance drops associated with communication on a single system, we are investigating whether a single set of Message Passing Interface (MPI) constructs can be used over multiple supercomputers in which the underlying MPI implementations differ greatly. Limitations of these implementations—such as scalability of MPI collectives, memory used by message passing libraries, and synchronization—are being examined in conjunction with the MPI constructs used by FUN3D.

By enabling the software to run more reliably and efficiently on the world's largest supercomputers, analysis and design cycle times can be dramatically lessened, ultimately reducing cost and turnaround times for a myriad of aeronautics and aerodynamics projects.

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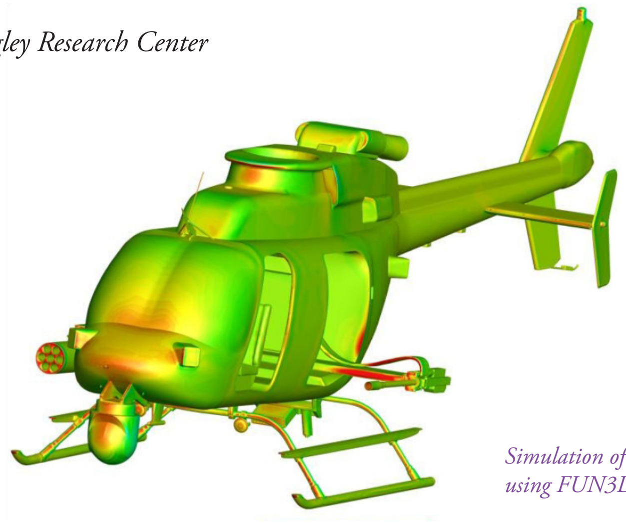

Simulation of an armed IA-407 helicopter performed using FUN3D. Tin-Chee Wong, US Army

High-Fidelity Simulations of Hypersonic Flows

Aeronautics Research Mission Directorate

An advanced computational fluid dynamics (CFD) code called ez4d is being used to simulate complex shock patterns and strong, unsteady waves resulting from surface protuberances and imperfections in the thermal protection systems of NASA's hypersonic vehicles. The ez4d solver is a time-accurate, unstructured mesh, Navier-Stokes code based on the state-of-the-art CESE (conservation element solution element) space-time numerical method. The fundamental physics formulations employed by ez4d enable it to generate high-fidelity numerical solutions for very complex hypersonic flows.

The primary objectives of these simulations are to understand transition flow physics due to roughness elements submerged in a hypersonic boundary layer; predict surface heating caused by transitional and turbulent boundary layers; and improve prediction of wake flows behind large, blunt bodies. These simulations will be used to assist parametric studies for future hypersonic vehicle designs. Another goal of this work is to develop software technologies for future multi-core computing architectures using combined Message Passing Interface (MPI) and multi-thread implementations.

Large-scale computations, using meshes with 10–100 million tetrahedral elements, are being performed on NASA's Pleiades supercomputer, which has enabled reasonable turnaround time for extensive parametric studies that would otherwise be impossible.

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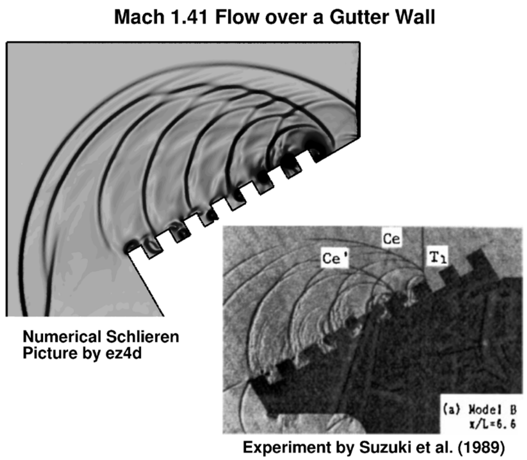

Comparison with experimental data for supersonic flow over a gutter wall.
Chau-Lyan Chang, NASA/Langley

High-Fidelity Simulations of Landing Gear Noise

Aeronautics Research Mission Directorate

Mitigation of aircraft noise is a critical goal of NASA's Aeronautics Research Mission Directorate. Airframe noise constitutes a major component of the total aircraft noise generated during approach and landing—with a significant portion attributed to the aircraft undercarriage.

Under a partnership with Gulfstream Aerospace Corporation, NASA Langley's Fully-Unstructured Navier-Stokes Three-Dimensional (FUN3D) computational fluid dynamics (CFD) code is being used to investigate the complex, unsteady flow around the nose landing gear of a G550 aircraft.

The landing gear produces an extremely complex flowfield that is highly interactive and nonlinear in nature. High-fidelity simulations of the unsteady flow around such complex landing gear requires very large calculations that can only be run on supercomputers. The combined capabilities of NASA's Pleiades supercomputer, mass storage, and post-processing expertise enable resolution and visualization of prominent flow features over a broad range of spatial and temporal scales.

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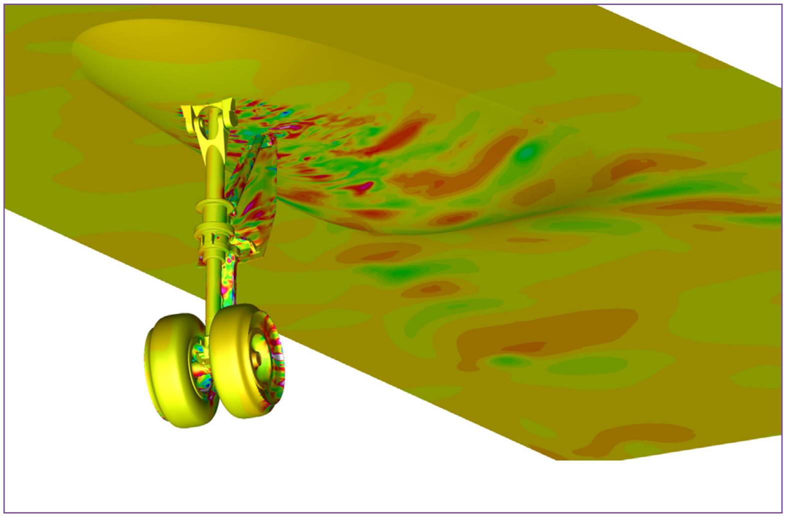


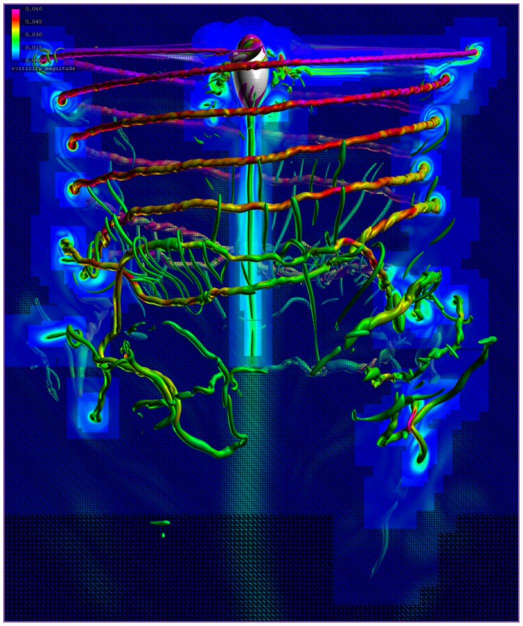
Fluctuating pressure field on nose landing gear and fuselage surfaces. *Airframe Noise Team, NASA/Langley*

High-Resolution Navier-Stokes Simulation of Rotorcraft Wakes

Aeronautics Research Mission Directorate

Helicopters and tiltrotor aircraft provide crucial services such as emergency evacuation, security patrols, and military operations. High-fidelity, physics-based simulations provide valuable insight into the complex aeromechanics and vortex phenomena involved in rotorcraft flight, helping engineers to reduce noise pollution and increase performance and heavy-lift capabilities in rotorcraft designs.

In support of NASA's Subsonic Rotary Wing Project, we are developing high-resolution computational fluid dynamics (CFD) simulation tools for rotorcraft applications. Using the OVERFLOW 2.2 CFD code, we have made several advancements in rotor wake simulation accuracy, including: use of 5th-order spatial accuracy for the Navier-Stokes equations to preserve vortex strength and reduce vortex diffusion in the flowfield; refinement of rotor blade surface resolution to improve predicted tip vortex strengths; and automated grid adaption to improve the resolution of wake vortices. With these techniques, we have been able to reduce vortex diameter error from 700% to 25%, and have improved prediction of the Figure of Merit for a hovering rotor (a measure of thrust and torque) to within 0.1% of the experimental value.



These high-resolution rotorcraft simulations require world-class supercomputing resources. A typical solution requires 35–500 million grid points, 256–4,096 processor cores, and two or more weeks of continuous computation. NASA's supercomputers and visualization capabilities enable verification and validation of these powerful computational tools, and provide new insight into the complex nature of rotor wakes.

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Navier-Stokes simulation of an isolated V-22 Osprey rotor in hover. Vortices are rendered with isosurfaces based on the Q-criterion. Two levels of grid adaption improve rotor vortex resolution and predict the Figure of Merit within experimental accuracy. Magenta is high vorticity and blue is low vorticity. *Neal Chaderjian, Timothy Sandstrom, NASA/Ames*

High-Speed Turbulent Boundary Layers and Interactions with Shock Waves

Aeronautics Research Mission Directorate

The design of supersonic and hypersonic vehicles depends strongly on the accurate prediction of turbulent flow characteristics and interactions in high-Mach boundary layers. Boundary layer turbulence has first-order impacts on aerodynamic heating, surface ablation, drag, and control of hypersonic vehicles during ascent and descent.

We are performing simulations of high-speed turbulent boundary layers, using a high-order hybrid shock-capturing scheme and a novel recycling-recycling approach to efficiently resolve the spatially developing boundary layer. Our results have shown that turbulence statistics for high-Mach number flows collapse to their incompressible counterparts when scaled using wall quantities, indicating that these statistics are affected primarily by variable thermodynamic properties rather than flow compressibility.

We are also performing simulations of shock wave turbulent boundary layer interaction (STBLI). A key element of STBLI is the unsteadiness of the shock wave and separation bubble, which can oscillate at a frequency significantly lower than the characteristic frequency of the incoming boundary layer. To capture these phenomena, we are utilizing large eddy simulation (LES), with a 6th-order compact difference scheme and localized artificial diffusivity for shock capturing, to simulate two canonical STBLI cases: the compression ramp, and the impinging oblique shock.

This work will help develop fundamental understandings of turbulent boundary layer characteristics and the associated surface heat fluxes, which will be critical to the design of next-generation high-speed aircraft and aerospace reentry vehicles.

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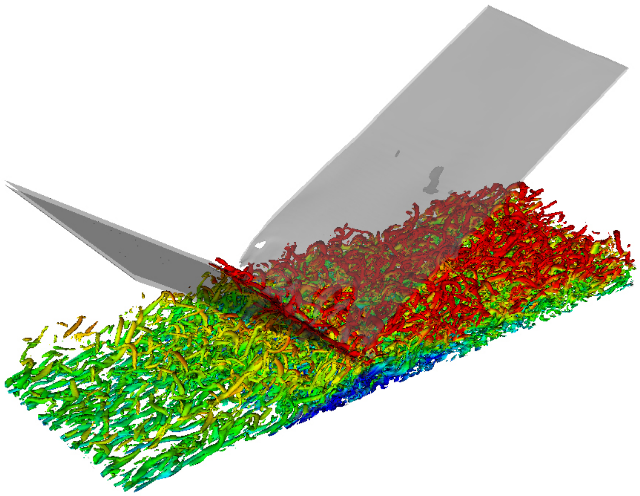

Oblique shock impinging on a hypersonic turbulent boundary layer for a Mach 2.05 flow over an 8-degree wedge angle. Isosurfaces of Q-criterion are colored by the streamwise momentum. The grey surfaces indicate location, and the dark blue surfaces indicate separation regions. *Sanjiva Lele, Parviz Moin, Stanford University*

Prediction of Jet Engine Fan Noise Using Computational Aeroacoustics

Aeronautics Research Mission Directorate

To support NASA's goal to improve aircraft performance while reducing noise, emissions, and fuel burn, we are providing a state-of-the-art computational code to predict the noise signature of a realistic jet engine fan.

The NASA Broadband Aeroacoustic Stator Simulation (BASS) computational aeroacoustics (CAA) code is designed to accurately predict the unsteady flow and noise in highly complex flows such as those in jet engine fans. This tool will be invaluable for developing methods for reducing fan noise with minimal performance penalties.

In this project, experimentally measured rotor wakes from the NASA Source Diagnostics Test are imposed upstream of the baseline stator, and the resulting noise is predicted. Two-dimensional results are shown here, and the extension to three dimensions is underway.

Even with the high-resolution capabilities of the BASS CAA code, a large number of grid points and time steps are required to accurately predict the unsteady flow and noise in a jet engine fan. Supercomputing and storage resources at the NASA Advanced Supercomputing (NAS) facility provide the enormous computational horsepower required to compute the flows and then store the resulting solutions.

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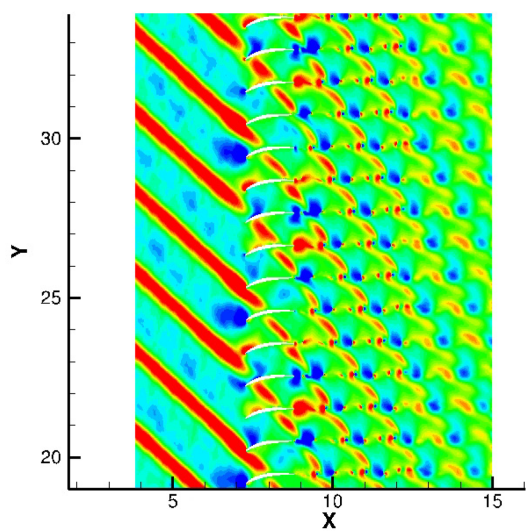

Snapshot of the interaction of rotor wakes with stator vanes at a radial location of 8.8 inches.
Duane Hixon, NASA/Glenn

Supercomputing for Aircraft Fuel Injector Swirler Design

Aeronautics Research Mission Directorate

Aircraft gas turbine combustor emissions—comprised of nitrogen oxides, carbon monoxide, sulfur dioxides, and particulates—are harmful to health and the environment. To help design cleaner-burning aircraft engines, the National Combustion Code (NCC) is being used to simulate the swirler mixing process in low-emission gas turbine combustor concepts. In engine combustors, the swirler is a critical component that enhances fuel-air mixing and creates a recirculation zone that stabilizes the combustion process.

In particular, the NCC is being used to model Lean Direct Injection (LDI) concepts designed to reduce nitrogen oxide emissions or smog, and to potentially decrease fuel consumption. To increase the predictive capability of the NCC, computational results are currently being validated against measurements from a research air-blast/air-assist fuel injector combustor at NASA Glenn Research Center.

Realistic modeling of gas turbine combustion requires solving complex, multi-disciplinary equations involving thermochemistry, fluid dynamics, heat transfer, mass transport, material science, and spectroscopy. NASA's highly parallel supercomputing resources enable these intensive computations, some of which require up to 4,000 processors to run. NASA's work with LDI and other lean combustion concepts has contributed to the development of jet engines that produce far less nitrogen oxides, helping to reduce smog, acid rain, asthma, and ozone layer depletion.

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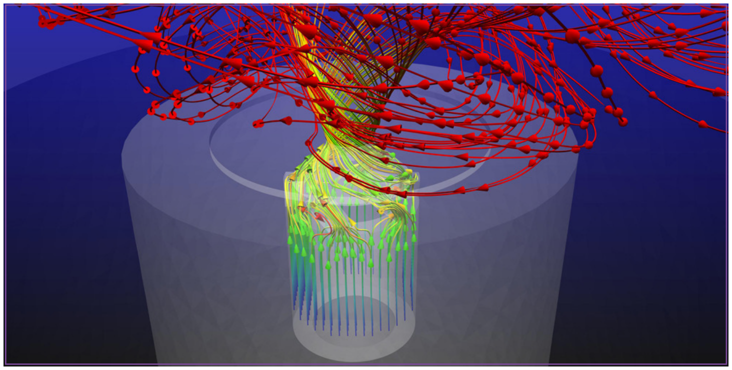

Stream-tubes show the airflow in the air-blast region of a research combustor. Air enters the concentric tube, is spun via a four-slot swirler, and then moves out of the fuel injector region with a tornado-like action. *Anthony Iannetti, NASA/Glenn*

Our Planet

3D Global Hybrid Simulations of Earth's Magnetosphere

Science Mission Directorate

As the global reliance on technology has increased, so has our exposure to the dangers of solar storms. The term "space weather" has been coined to describe the conditions in space that affect the Earth and its technological systems.

Our research in space weather focuses on 3D global hybrid simulations of the Earth's magnetosphere—long considered the "holy grail" in space physics. Using our advanced hybrid code, we have performed one of the largest 3D simulations to date, using 25 thousand cores on NASA's Pleiades supercomputer.

These simulations are, for the first time, enabling a glimpse of the global magnetosphere while capturing the full ion kinetic effects. Our initial problem targets reconnection at the dayside magnetopause. Initial results have yielded key discoveries regarding the formation of flux ropes at the magnetopause.

Global hybrid simulations generate massive datasets. A single run for this data-intensive computing application can generate over 200 terabytes of data. In order to extract physics from these data, we run algorithms on a large number of Pleiades' cores in a pre-visualization stage. The results are then made available for scientific visualization.

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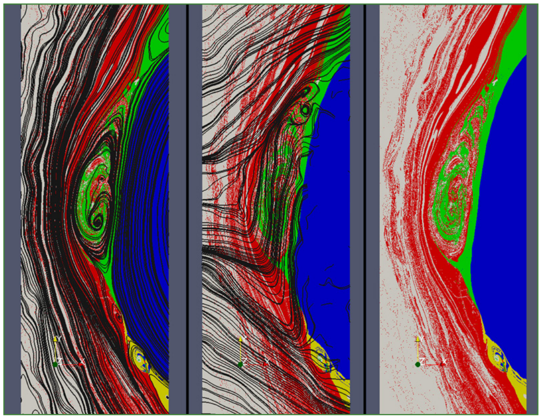

Left panel shows the magnetic field lines; middle panel shows the formation of a vortex in the flow generated by the passage of a flux rope; right panel shows the contours of density. *Burlen Loring, Homa Karimabadi, University of California, San Diego/SciberQuest*

Earth System Grid Data, Analysis, and Visualization Tools

Science Mission Directorate

Climate research is of great national importance. From model developers to policy makers, there is an overarching need to efficiently access and manipulate climate model data. The Earth System Grid (ESG) was established to meet the need for a common virtual environment in which to access both climate model datasets and analysis tools. The NASA Center for Climate Simulation (NCCS) at Goddard Space Flight Center is integrating an ESG Data Node into its Data Portal infrastructure to publish simulation datasets for the national and international climate community.

The ESG supports the NASA mission to observe Earth from space and to use data gathered in a scientific research program to better understand our planet as a system and how changes to that system will impact humankind, particularly changes in climate. This effort will multiply the value of NASA's investment in Earth observation by making NASA data more easily available to the broader science community.

Climate change potentially impacts the life of every person on the planet. The ESG was used to supply climate simulation data to scores of scientists who contributed to the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report. This report was instrumental in earning the IPCC a co-share of the 2007 Nobel Peace Prize, along with former U.S. Vice President Al Gore.

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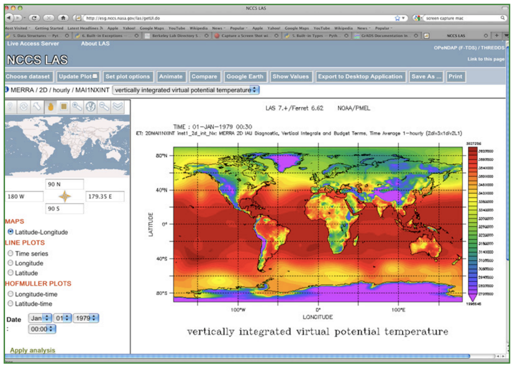

Earth System Grid (ESG) data displayed using the NCCS Live Access Server (LAS).
Thomas Maxwell, Ying Shen, NASA/Goddard

A Giga-Particle Atmospheric Trajectory Model

Science Mission Directorate

We present the Giga-Particle Atmospheric Trajectory Model (GTRAJ), a new parallel implementation of an atmospheric modeling trajectory framework that provides improved numerical accuracy, greater flexibility for specifying experiments, and sufficient raw performance to simultaneously simulate billions of parcel trajectories on suitable computing platforms. The ability to treat such large numbers of parcels is expected to enable a new generation of experiments to explore questions related to global stratosphere-troposphere exchange, age-of-air spectra, and transport of trace gases and aerosols.

The GTRAJ modeling framework is written in C++ for easy integration with other computing technologies. It is also parallelized using the Message Passing Interface (MPI) library, so that it can scale efficiently on a wide variety of modern computing platforms. GTRAJ was developed using Test-Driven Development (TDD), which provides confidence in the implementation and assists other developers who may wish to extend the framework.

The Discover supercomputer at the NASA Center for Climate Simulation (NCCS) has enabled us to carry out the massively parallel computations required for these trajectory simulations. Furthermore, NCCS supercomputing resources have allowed us to develop new approaches to solving problems that are not well addressed by non-parallel trajectory models.

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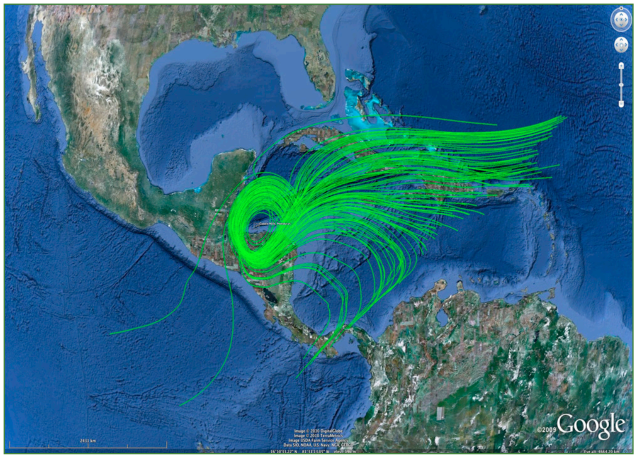


Hurricane Mitch kinematic trajectories at 9 kilometers, initialized for October 27, 2004 at 00UT using Modern Era Retrospective-analysis for Research and Applications (MERRA) reanalysis data. The trajectory model moves a tropical cyclone along based on the prevailing flow obtained from a separate dynamical model—the Goddard Earth Observing System Model, Version 5 (GEOS-5) in this case. *Shawn Freeman, Carlos Cruz, NASA/Goddard*

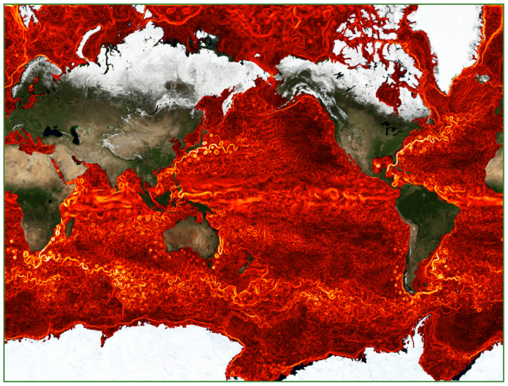
High-End Ocean State Estimates: Application to Real-World Challenges

Science Mission Directorate

NASA has unique capabilities in developing and deploying advanced satellite observing systems. Data from these instruments allows us to develop scientific insights into how (and why) the global earth system is changing, and to improve the understanding of life-supporting planetary cycles.

Under the Estimating the Climate and Circulation of the Ocean 2 (ECCO2) project, scientists at NASA and MIT are working together, using advanced computation to reconstruct the state of the Earth's ocean and sea-ice system. These three-dimensional, time-evolving reconstructions result in detailed information about variations in quantities such as ocean current patterns and temperature, sea-ice cover, global mass distribution, and sea level—spanning nearly 20 years.

In addition to helping develop a core understanding of how the ocean and sea-ice systems work, this information provides scientific input into real-world issues, including: monitoring the ocean-atmosphere exchange of carbon dioxide; forecasting the likely impact of pollutant plumes, such as the Deepwater Horizon; and improving estimates of Antarctic glacial melting.



Surface current speeds from a 1/16-degree-resolution simulation. The currents and associated 3D full ocean state can be used to drive applications such as: improved melt-rate estimates for the Antarctic ice sheet; enhanced estimates of ocean carbon dioxide uptake due to physical and biological processes; and quantification of uncertainty in projections of surface pollutant transports. *Chris Henze, NASA/Ames*

We have developed simulation tools uniquely suited to combining models and observations to monitor the ocean and sea-ice climate. Our computations have data-intensive characteristics, and require thousands of compute cores, hundreds of terabytes of permanent storage, and multiple terabytes of RAM in an iterative optimization process. NASA supercomputers are among the few available platforms that can handle the scale of computation, data processing, analysis, and visualization required.

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NASA Center for Climate Simulation: Data Supporting Science

Science Mission Directorate

Debuting in spring 2010, the NASA Center for Climate Simulation (NCCS) is the new name for a Goddard Space Flight Center organization that has served NASA scientists and engineers for over 25 years.

NCCS offers integrated supercomputing, visualization, and data interaction technologies to enhance Agency capabilities in weather and climate prediction. Its centerpiece is the Discover supercomputer, which recently doubled in capability to nearly 30,000 processors and 320 teraflops peak performance.

In addition to a powerful supercomputer, NCCS supports users with a massive data archive, a new data management system, expanded data analysis and visualization capabilities featuring a 17-ft. by 6-ft. visualization wall, and services for distributing simulation data to users and the broader climate research community.

Among other benefits, NASA weather and climate simulations help to determine the optimal use of the latest satellite observations in predictions, ultimately leading to increased accuracy of weather and climate forecasts by operational agencies such as the National Oceanic and Atmospheric Administration (NOAA) and its National Weather Service.

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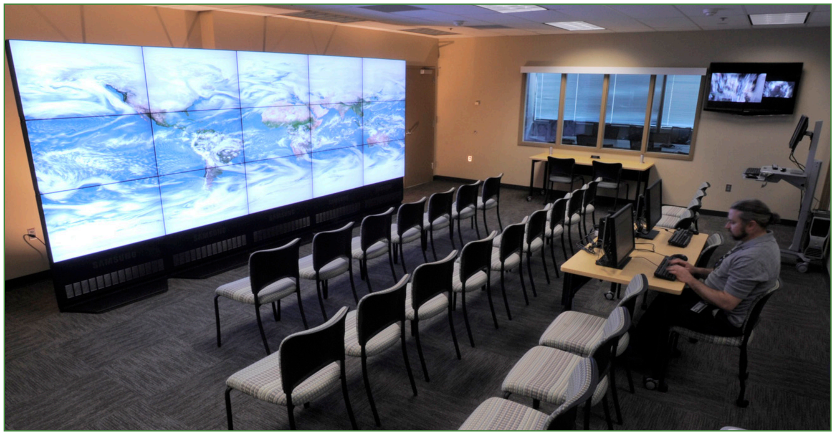


The NASA Center for Climate Simulation (NCCS) Data Exploration Theater features a 17-ft. by 6-ft. multi-screen visualization wall. Here, the wall displays a 5-kilometer-resolution global simulation capturing the massive snowstorms that hit the eastern United States in February 2010. *Pat Izzo, NASA/Goddard*

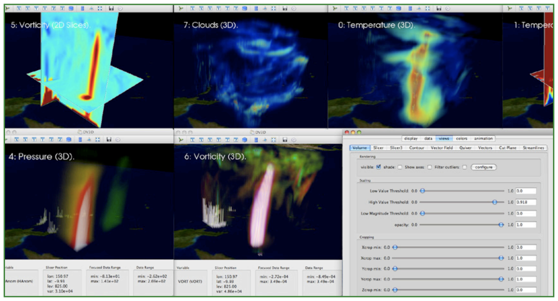
NCCS Climate Simulation Data Analysis

Science Mission Directorate

Climate change impacts the life of every person on our planet. The climate simulation data analysis work at the NASA Center for Climate Simulation (NCCS) at Goddard Space Flight Center will contribute directly to ongoing analysis and assessment of the state of the global climate system.

Earth system scientists are experiencing an explosion of data generated by the ever-increasing resolution in global models and remote sensors. The growing size of the datasets makes scientific analysis using desktop applications increasingly difficult—prompting the need for high-performance data analysis and visualization capabilities closely linked to data archives. To meet this need, NCCS installed a high-performance server for large-scale data analysis and visualization.

This effort directly supports the NASA mission to use remote sensing data and global models to better understand Earth system dynamics. Analysis of observational and model data is essential to understanding how changes to Earth system processes (for example, climate) will impact humankind. This effort will facilitate the analysis of Earth system data by both Agency scientists and a broader audience through the Earth System Grid.



The DV3D application provides distributed, user-friendly 3D visualization tools for the climate scientist's desktop or hyperwall.

This service allows unprecedented access to high-performance data and processing applications to facilitate climate data analysis operations in support of Earth system science that would otherwise be very difficult or impossible.

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Recent Advances in Global Hurricane Modeling after Katrina

Science Mission Directorate

NASA's major hurricane research activities focus on improving our understanding of how tropical storms form, develop, and intensify. Knowledge gained from this research could ultimately save lives and reduce property damage.

Since Hurricane Katrina (2005), we have worked on "discovering predictive relationships between meteorological and climatological events and less obvious precursor conditions from massive datasets," one of the top priorities of the National Research Council 2007 Decadal Survey report, *Earth Science and Applications from Space: National Imperatives for the Next Decade and Beyond.*

To achieve this, we integrate NASA's high-resolution global model and concurrent visualization techniques on the Pleiades supercomputer to produce high-resolution simulations that improve our understanding of mesoscale predictability for tropical cyclones (TCs), and to extend the lead time of predicting TCs by the interactions of (for example) different kinds of large-scale tropical waves.

Each high-resolution simulation requires hundreds or thousands of processors and up to 4 terabytes of disk space per run. 3D visualizations of high-resolution temporal and spatial simulations are generated using NASA's concurrent visualization tools to improve our understanding of complicated multi-scale interactions.

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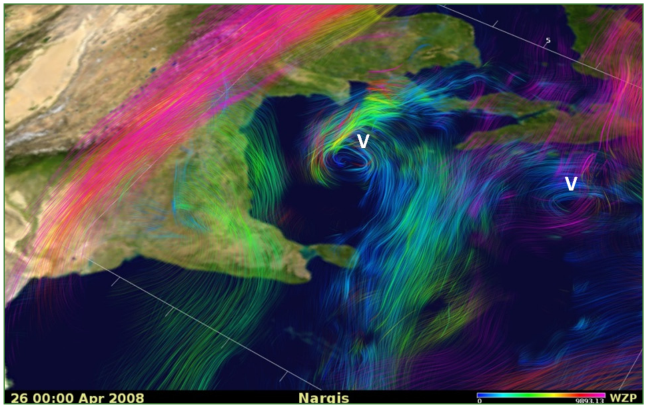

Genesis of the very severe cyclonic storm Nargis (2008) associated with the equatorial Rossby wave: (a) A pair of low-level vortices at 96h simulation (labeled with 'V') indicate formation of the Rossby wave. Cyclone Nargis formed when the northern vortex strengthened. *Bryan Green, NASA/Ames; Bo-wen Shen, NASA/Goddard*

Toward GEOS-6, a Global Cloud System Resolving Atmospheric Model

Science Mission Directorate

NASA is committed to observing and understanding the weather and climate of our home planet through the use of multi-scale modeling systems and space-based observations. Global climate models have evolved to take advantage of the influx of multi- and many-core computing technologies and the availability of large clusters of multi-core microprocessors.

GEOS-6 is a next-generation cloud system resolving atmospheric model that will place NASA at the forefront of scientific exploration of our atmosphere and climate. Model simulations with GEOS-6 will produce a realistic representation of our atmosphere on the scale of typical satellite observations, bringing a visual comprehension of model results to a new level among climate enthusiasts.

In preparation for GEOS-6, the Agency's flagship Goddard Earth Observing System (GEOS) Model has been enhanced to support cutting-edge, high-resolution global climate and weather simulations. Improvements include a cubed-sphere grid that exposes parallelism; a non-hydrostatic finite-volume dynamical core; and algorithms designed for co-processor technologies, among others.

GEOS-6 represents a fundamental advancement in the capability of global Earth system models. The ability to directly compare global simulations at the resolution of spaceborne satellite images will lead to algorithm improvements and better utilization of space-based observations within the GEOS data assimilation system.

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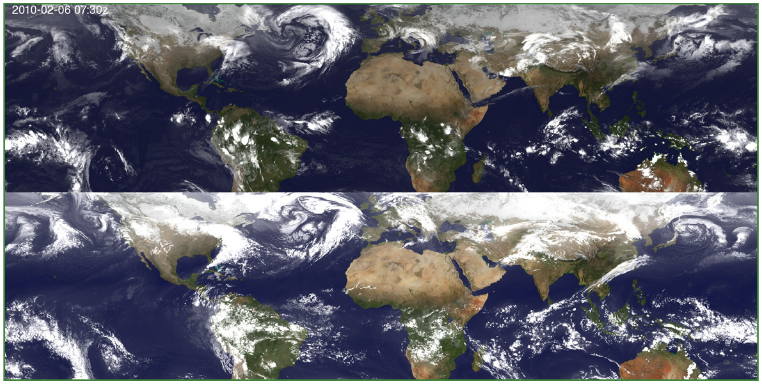


These images compare clouds as seen via infrared imagery from a 5-kilometer (km) GEOS-5 simulation (bottom) with observations from the Geostationary Operational Environmental Satellite (GOES) (top). The images show a snapshot of clouds 80 hours into a 20-day simulation from February 2, 2010. *William Putman, NASA/Goddard*

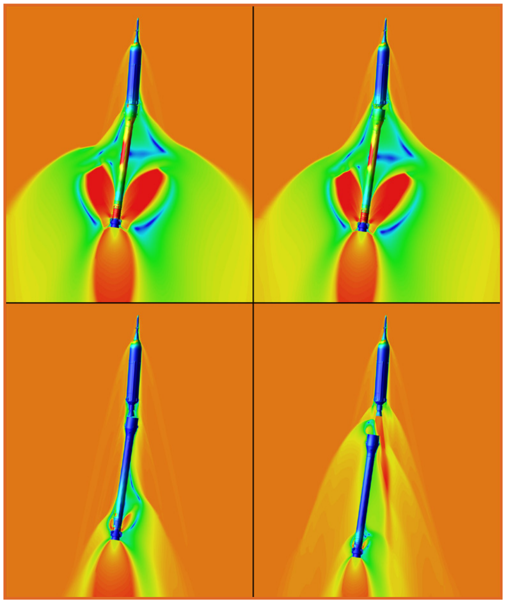
Space Exploration

Aerodynamics of the Ares I Crew Launch Vehicle During Stage Separation

Exploration Systems Mission Directorate

A team of modeling and simulation experts at the NASA Advanced Supercomputing facility has performed high-fidelity computational fluid dynamics (CFD) simulations of stage separation for the Ares I Crew Launch Vehicle. These simulations model the complex aerodynamic forces and interactions that play a crucial role during separation of the vehicle's first stage solid rocket booster from its upper stage engine during ascent.

These high-fidelity analyses are performed using the viscous CFD code OVERFLOW with high-resolution computational grids including complex geometrical details of the vehicle. The team modeled a wide range of separation conditions covering different Mach numbers, flight angles, separation distances, and angles between the two stages. Extensive powered stage separation simulations also modeled plume effects from the vehicle's various stage separation motors and assessed numerous off-nominal scenarios with some motors not functioning.



The intensive analyses needed to capture the complex flow physics involved in stage separation are computationally demanding, requiring upwards of 1,000 processors and one to two weeks of run-time on NASA's Pleiades supercomputer for each case, and generating several hundred terabytes of data overall. This critical aerodynamic data is used to help design the Ares I launch vehicle and develop a safe, effective stage separation system.

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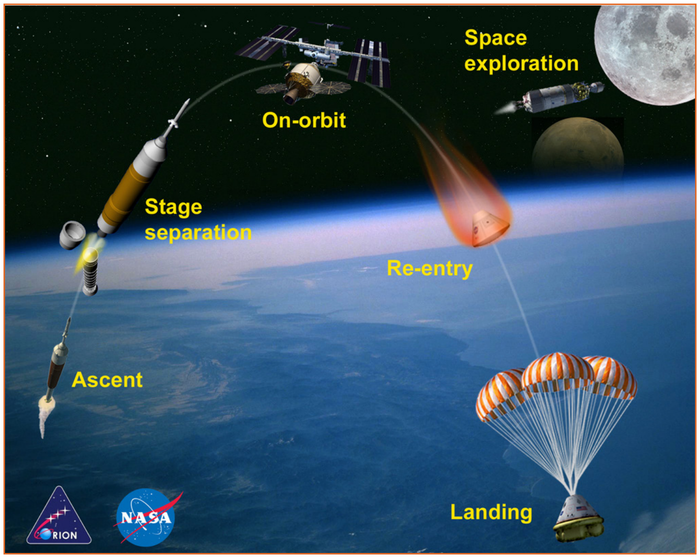
Visualization of stage separation flow physics, starting from the firing of the booster deceleration motors and ullage settling motors (upper left), and ending with the start-up of the J-2X motor on the upper stage (lower right). *Jeff Onufer, Henry Lee, NASA/Ames*

Analysis of Orion Crew Exploration Vehicle Reentry Flow Environments

Exploration Systems Mission Directorate

Advanced simulations of the Orion Crew Exploration Vehicle (CEV) during atmospheric reentry are supporting the design of the vehicle's thermal protection system (TPS) and reentry maneuvering control system. These analyses predict surface heating for TPS design, assess flow interactions and surface heating caused by the descent maneuvering jets, and model unsteady wake flows behind the vehicle to determent their effect on aerothermal heating and aerodynamics. Analyses are also being performed to reduce uncertainties associated with complex, chemically reactive flows, in which chemical properties and reactions play an important role in gas properties and dynamics.

These analyses are performed using a computational fluid dynamics (CFD) flow solver called the Langley Aerothermodynamic Upwind Relaxation Algorithm (LAURA). Using CFD to model complex flow phenomena provides more accurate prediction of quantities needed for TPS assessment, enabling NASA to design the CEV with smaller weight tolerance margins while still ensuring proper protection for the crew.



Mission profile for the Orion Crew Exploration Vehicle (CEV). *NASA/Langley*

Extensive supercomputing resources are needed to compute the complex flow structures involved in Orion's wake region, which is highly separated, chemically reacting, and unsteady. Each LAURA calculation solves for over 200 million unknown quantities and requires approximately 31,000 processor-hours on NASA's Pleiades supercomputer for each trajectory point analyzed. This detailed data plays a key role in understanding CEV reentry environments to design a vehicle that will bring astronauts home safely.

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CFD Support for Heavy Lift Launch Vehicles

Exploration Systems Mission Directorate

Computational fluid dynamics (CFD) simulations assist in the design of next-generation heavy lift launch vehicles (HLLVs) and improve our understanding of launch vehicle aerodynamics during ascent. NASA-developed CFD flow solvers are used to predict aerodynamic load distributions on the Ares V HLLV in support of trajectory development and structural analysis. These simulations supplement experimental wind tunnel data and extend predictive capabilities to full-scale flight vehicles.

Extensive analyses of evolving Ares V HLLV designs were performed over several design cycles. Analyses included: validation studies with wind tunnel test data; analysis of aerodynamics throughout the ascent trajectory; investigations of rocket plume effects; shape trade studies to optimize payload shroud design; evaluation of protuberance contributions to aerodynamic loads; solid rocket booster (SRB) separation simulations with plume interactions; and analysis of high-altitude high-Mach conditions that cause plume-induced flow separation and associated risks such as base heating. Prior to this design support work, CFD best practices were developed to assess key analysis criteria such as grid resolutions, turbulence models, discretization schemes, and levels of physical modeling fidelity such as inviscid, viscous, and multi-species models.

Solid rocket booster separation maneuver for Ares V, showing plume isocontours colored by pressure. *Marshall Gusman, NASA/Ames*

NASA's supercomputing resources enable massively parallel computations with high-fidelity models, while powerful postprocessing and visualization tools facilitate interactive examination of complex 3D solutions that would otherwise be too large to inspect. With these capabilities, scientists can quickly compute entire aerodynamic databases and analyze many designs and conditions.

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Computational Fluid Dynamics for the CEV Aerosciences Project

Exploration Systems Mission Directorate

Computational fluid dynamics (CFD) simulations support the design and analysis of NASA's Orion Crew Exploration Vehicle (CEV) and crew module. A range of CFD analyses are conducted to assess key aspects of vehicle performance during launch aborts, atmospheric entry, descent, and landing.

CFD simulations of the Launch Abort Vehicle (LAV) and Orion crew module are used to predict aerodynamic performance and extend wind tunnel test data to flight operating conditions. Analyses of the LAV are also performed to predict abort motor plume expansion and heat transfer at flight operating conditions, and to assess the vehicle's stability and control, including complex interactions between its hardware, attitude control motor, and abort motor plumes. Further simulations model the wake behind the Orion crew module during atmospheric entry and descent to support design and analysis of the parachute deployment system.

These CFD simulations provide the CEV Aerosciences Project with key performance predictions for conditions that are difficult, or impossible, to obtain using ground-based or flight testing. NASA supercomputing resources enable efficient prediction of the aerodynamic performance and flow physics for complex geometries across a complete design space.

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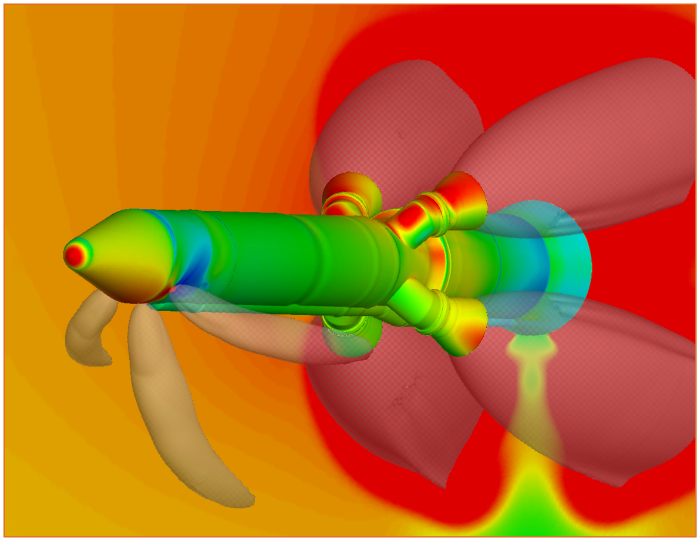

Mach contours and isosurfaces highlight the complex flowfield of the Launch Abort Vehicle.
Tom Booth, Ray Gomez, NASA/Johnson

Error-Controlled Simulation Database for Orion Pad Abort Test

Exploration Systems Mission Directorate

An extensive, error-controlled database of aerodynamic simulations has been generated to support the Pad Abort 1 (PA-1) flight test of the Orion Launch Abort Vehicle (LAV), which is designed to carry the Orion crew module safely away from the launch vehicle in the unlikely event of a catastrophic failure during ascent.

NASA supercomputing resources enabled thousands of numerical simulations to be performed, providing a detailed, quantitative understanding of the vehicle's performance through several design iterations, from concept development through its highly successful flight test. Over 15,000 numerical simulations were performed at the NASA Advanced Supercomputing facility to predict aerodynamic performance and flight loads on the vehicle for the PA-1 test flight. Most of these cases were modeled using NASA's Cart3D computational fluid dynamics code. The simulations also employed a new error-control capability that selectively adapts key regions of the model's computational mesh to minimize resolution-related error in the aerodynamic loads.

Flight loads and aerodynamic performance data from these simulations were used to develop the guidance and control (G&C) system for the vehicle, assess structural design criteria, and ensure that the Orion crew module could separate safely from the rest of the LAV. The design support provided by this data contributed to the success of the PA-1 flight test conducted at the White Sands Test Facility on May 6, 2010.

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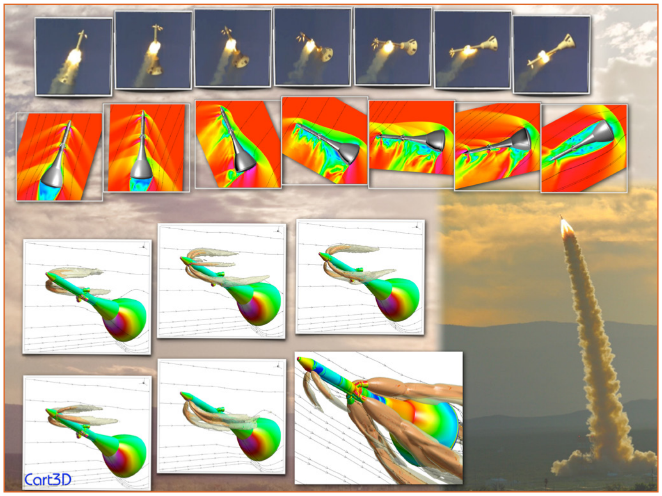

Snapshots from the flight test and numerical simulations performed with NASA's Cart3D code. Simulations were used to develop an aerodynamic database for performance prediction and structural loads, which helped guide vehicle design. *Michael Aftosmis, NASA/Ames*

Hypersonic CFD Space Shuttle Simulations

Space Operations Mission Directorate

Computational fluid dynamics (CFD) simulations provide high-fidelity assessment of possible damage to the Space Shuttle, in support of the shuttle's Damage Assessment Team. Using the powerful and reliable computing resources at the NASA Advanced Supercomputing (NAS) facility, researchers are able to employ these simulations in near real-time to assess damage and repair scenarios during shuttle operation.

Rapid hypersonic CFD simulations of damaged and repaired regions are increasingly important for real-time risk assessment during vehicle operations. Localized CFD simulations allow researchers to investigate small features on the shuttle, while leveraging existing high-fidelity simulations completed before the missions. This technique provides rapid turnaround during missions, producing results within hours instead of days or weeks.

Parallel CFD codes, such as NASA Ames Research Center's DPLR (Data Parallel Line Relaxation) flow solver, are used to understand thermal protection system damage, as well as to develop flight experiments and confidently design the next generation of reentry vehicles. Additionally, NAS resources are used throughout the year to develop new simulation capabilities and help design future flight experiments.

Recently, the Space Shuttle Program approved the installation of small, instrumented protuberances on the underside of the shuttle. Data gathered from these instruments during recent shuttle missions will help engineers better characterize chemically reactive high-speed flows, both for remaining shuttle flights and future reentry vehicles.

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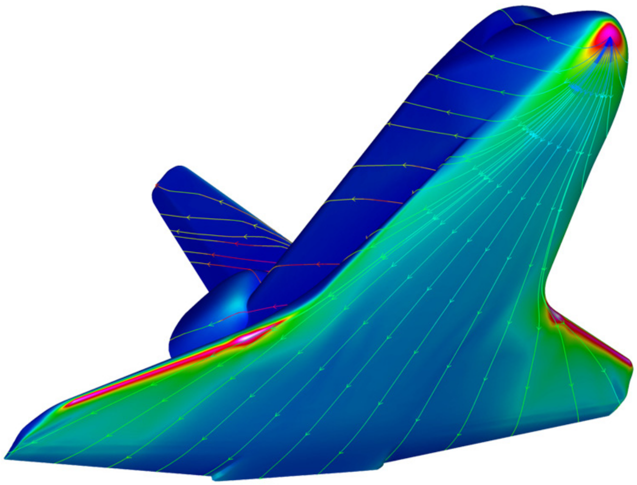

DPLR computational fluid dynamics simulation of instantaneous heating on the Space Shuttle. *Todd White, NASA/Ames*

Jet Interaction Effect of Ares I Launch Vehicle Roll Control System

Exploration Systems Mission Directorate

Researchers at NASA Langley Research Center have created a database to quantify rolling moment and control uncertainties used for developing the Ares I launch vehicle's roll control system (RoCS). Databases of rolling moment coefficients, as well as jet and free-stream interaction effects of the Ares I RoCS in flight, are important for analyses of the guidance, navigation and control (GN&C) system throughout the vehicle's ascent phase.

This work involves the creation of an aerodynamic database from 220 computational fluid dynamics (CFD) test cases for the Ares I (A106 configuration) RoCS jet interaction effect. The database was built in a three-month timeframe—using CFD alone—to meet the GN&C project deadline. The availability of NASA's supercomputers, storage, and high-speed networks was crucial to the feasibility of this work, as obtaining experimental data would have been technically complex and time consuming.

Project work includes: establishing flow conditions and constructing an optimized run matrix; computing flow solutions for RoCS jets both at idle and in action; analyzing the force and moment coefficient increments for all cases and examining flow physics details of selected cases; and interpolating the computed results at 220 discrete flow conditions.

This work represents an increase in scalability of the best-known NASA CFD codes to a level commensurate with industrial expectations in both speed and quality.

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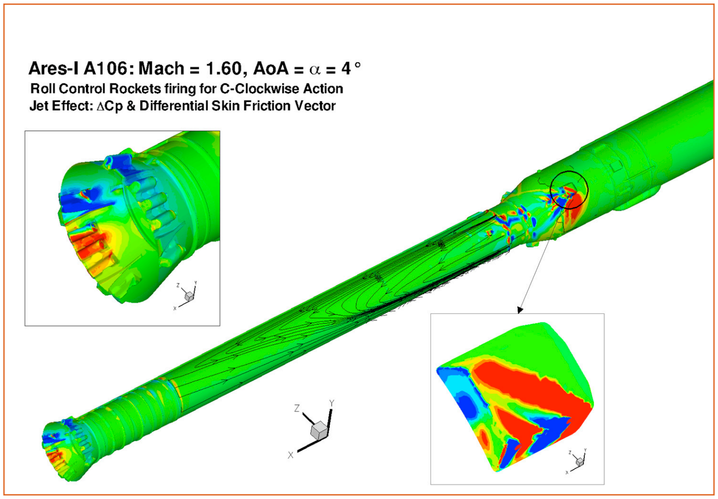

Sample result for RoCS effects at Mach=1.60 and angle-of-attack=4°: differential pressure coefficient and skin-friction vector trace. *S. Paul Pao, NASA/Langley*

Launch Environment Simulations

Exploration Systems Mission Directorate

Computational tools and techniques have been developed to simulate the launch environment for NASA's future heavy lift launch vehicles (HLLVs). This work includes simulation of the ignition overpressure (IOP) phenomenon, in order to predict pressure loads on the vehicle and launch pad trench walls.

In addition, computational methodologies have been established to predict acoustic noise sources and sound propagation during liftoff. Acoustic noise is generated by exhaust jets and their interactions with the launch tower, platform, and trench. The acoustic waves then propagate in all directions and interact with the launch vehicle and tower, potentially causing oscillations that could damage the payload. Computational fluid dynamics (CFD) simulations of HLLV launch environments have yielded IOP and acoustic level results in agreement with flight data and empirical prediction methods, validating the approach's accuracy for future vehicles.

Accurate characterization of acoustic environments and sound pressure levels during liftoff is an important step toward the development of new HLLVs. This work helps assess the suitability of existing launch facilities for larger vehicles, and will help ensure successful HLLV launches. Advancing technology to predict acoustic noise could also benefit noise reduction efforts for everyday vehicles, such as cars, trains, and airplanes.

NASA supercomputing resources enable both the large-scale simulations required to resolve the complex physics involved, and the large parameter studies needed to develop sound computational methodologies.

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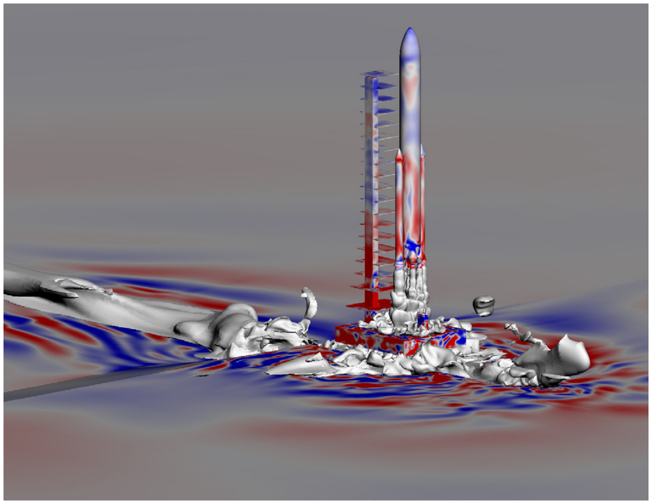

Gauge pressure contours are shown on the Ares V vehicle and surrounding structures, and exhaust gases are depicted by an isocontour at 5% concentration. Note that acoustic pressure waves radiate predominantly in the direction of the flame trench. *Jeffrey Housman, NASA/Ames*

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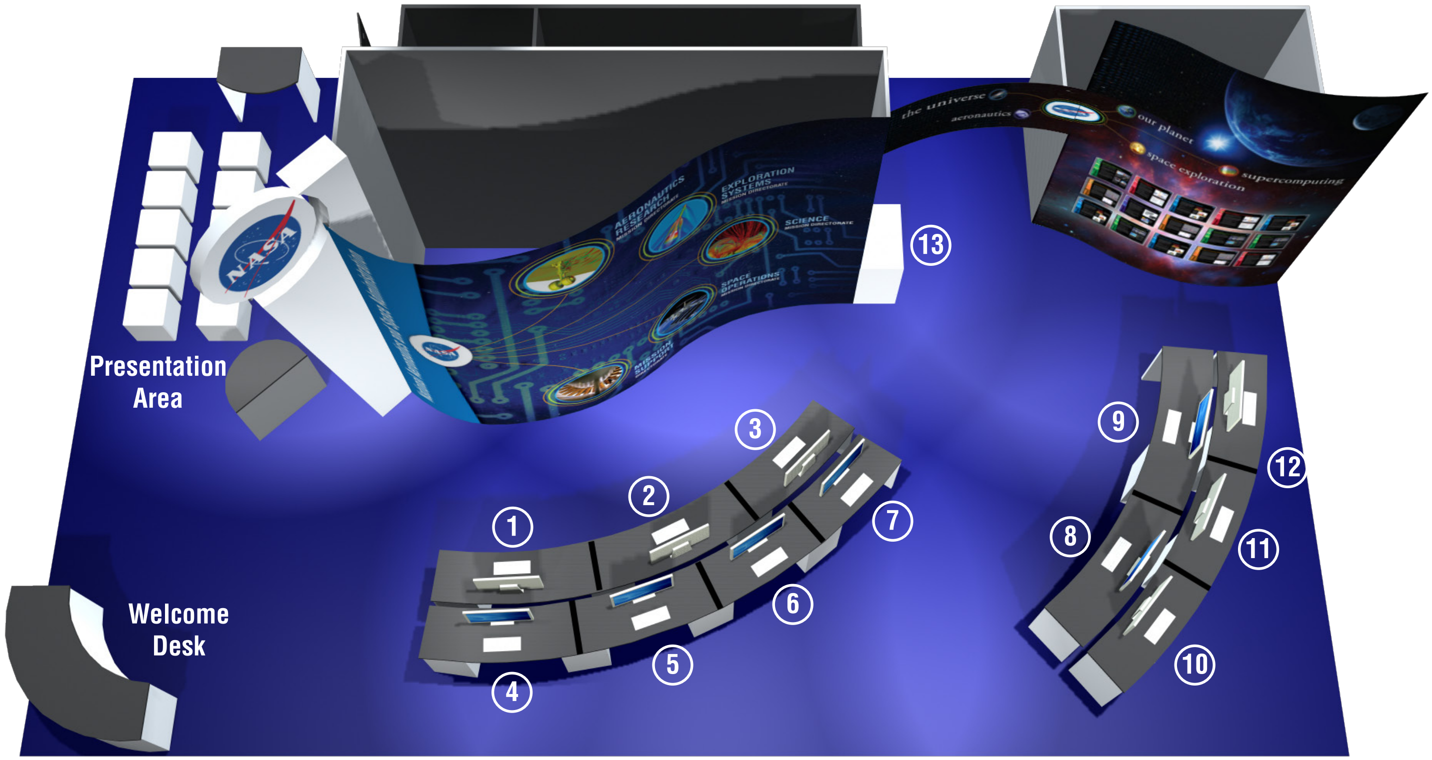

RESEARCH AREA	DEMO TITLE	PRESENTER	LOCATION
Aeronautics	Computational Scaling for an Unstructured-Grid CFD Solver	Eric J. Neilsen	1
	High-Fidelity Simulations of Hypersonic Flows	Balaji Venkatachari	1
	High-Fidelity Simulations of Landing Gear Noise	Mehdi Khorrami, David Lockard	1
	High-Resolution Navier-Stokes Simulation of Rotorcraft Wakes	Neal Chaderjian	2
	High-Speed Turbulent Boundary Layers and Interactions with Shock Waves	Seokkwan Yoon	2
	Prediction of Jet Engine Fan Noise Using Computational Aeroacoustics	Richard Rinehart	2
	Supercomputing for Aircraft Fuel Injector Swirler Design	Anthony Iannetti	3
Our Planet	3D Global Hybrid Simulations of Earth’s Magnetosphere	Homa Karimabadi, Burlen Loring	3
	Earth System Grid Data, Analysis, and Visualization Tools	Thomas Maxwell, Yingshuo Shen	3
	A Giga-Particle Atmospheric Trajectory Model (GTRAJ)	Rahman Syed	4
	High-End Ocean State Estimates: Application to Real-World Challenges	Chris Hill	4
	The NASA Center for Climate Simulation: Data Supporting Science	Phil Webster	P
	NCCS Climate Simulation Data Analysis	Thomas Maxwell	P
	Recent Advances in Global Hurricane Modeling after Katrina	Bo-wen Shen	8
	Toward GEOS-6, a Global Cloud System Resolving Atmospheric Model	William Putman	P

Space Shuttle Debris Transport Assessments

Space Operations Mission Directorate

The Space Shuttle Program, one of the most visible NASA programs, is the end result of one of the modern world's most complex engineering efforts. Balancing the requirement for a lightweight structure against the harsh environments encountered during launch and reentry is a challenging task. These factors, combined with the presence of high-speed debris, add to the complexity and have required probabilistic risk assessment to quantify the associated risks.

Characterizing the wide range of potential debris sources that can impact the Space Shuttle launch vehicle is a another challenging task. Our software tools support prelaunch, inflight, and postflight shuttle debris evaluations. Prior to launch, these tools are used to determine if unusual ice and foam defects pose a threat to the vehicle. During flight, damaged or protruding pieces of insulation on the Orbiter can be assessed to help determine if on-orbit repairs are required.

Simulating the release and transport of debris, and comparing the impact conditions to the Shuttle thermal protection system's impact capability requires a large number of simulations that must be performed in a relatively short time. NASA's supercomputing resources provide the computational power and storage needed to simulate the shuttle ascent and entry flowfields, and predict debris impact conditions and damage.

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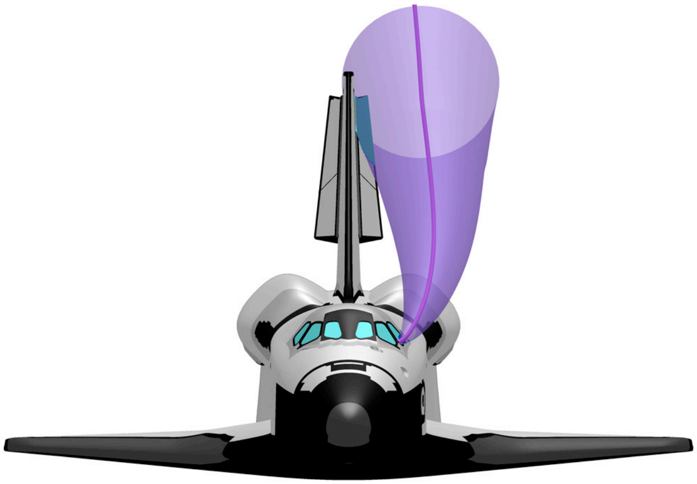

Simulation of the impact conditions of a thermal protection tile plug during reentry. *Reynaldo Gomez, NASA /Johnson*

Supercomputing

Climate-in-a-Box System Overview

Science Mission Directorate

NASA has a goal to broaden the audience for model development, promoting cross-institutional collaboration with code and data sharing. The Climate-in-a-Box (CIB) project produces a complete, ready-to-use toolkit of climate research products for investigators, with a focus on ease-of-use and collaboration.

CIB was designed for smaller "desktop supercomputers" and Linux clusters to enable rapid development and quick turnover. The goal is for users to utilize these smaller platforms for testing coarse-resolution runs, and then later transition to large supercomputing clusters for production runs.

Reproducibility is a priority for the project, both to ensure accurate science and to allow scientists to return to NASA's supercomputing clusters to perform larger experiments. This approach helps scientists remain productive with their time and computational hours, and also frees up the supercomputers, such as the Discover cluster at the NASA Center for Climate Simulation, to run larger, higher-resolution experiments.

The CIB project has a core focus in "open" model development, which can positively impact global climate change research by enabling greater cooperation in the research process. A Distributed Modeling System aspect of the CIB project studies the issue of establishing a system with data-sharing across several institutions to promote collaboration.

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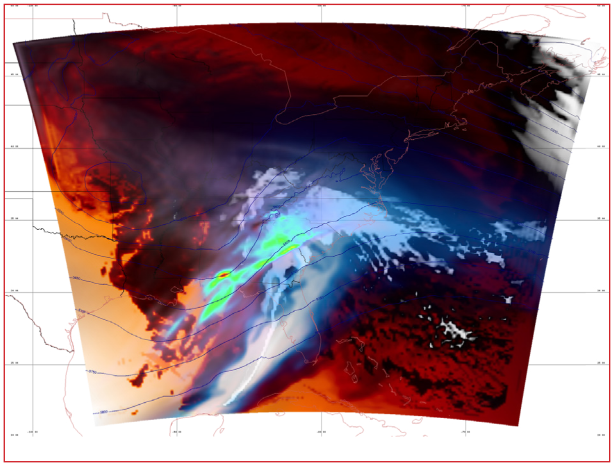

View from a Weather Research and Forecasting (WRF) Model simulation of the February 5–6, 2010 U.S. East Coast "Snowmageddon" storm. This image overlays surface downward flux (orange-black) with mid-atmosphere humidity (blue-white), geopotential height (blue contours), and cumulative precipitation (green/blue/red). *Phil Hayes, John Evans, NASA/Goddard*

Climate Simulation Acceleration

Science Mission Directorate

High-resolution climate models have opened up a new area for global climate change and simulation research, and are becoming valuable tools for improving forecasting of hurricane tracks and other aspects of hazardous weather. Accelerator technology is playing an active role in heterogeneous computing technology and research advances.

Currently, climate simulations pose a serious challenge for computing platforms based on conventional multi-core processors, in terms of simulation duration and scalability. Accelerator technologies like the IBM Cell Broadband Engine (Cell BE) and NVIDIA graphics processing units (GPUs) provide an opportunity for managing this challenge. However, their programming models are closely related to the underlying architectures and differ significantly from existing ones such as Message Passing Interface (MPI) and OpenMP.

When adapting real-world applications such as climate simulations to accelerators, the challenges due to these differences are greatly amplified. Our work focuses on answering the following questions. What is the ratio of performance gain to costs, both human and system? How can the accelerated codes survive in next-generation accelerators?

In this project, representative climate codes have been ported to prototypes of hybrid computing systems (Intel processors connected to the IBM Cell BE or NVIDIA GPUs) to address such questions. The answers will help determine how to incorporate these accelerator technologies in computing platforms to effectively, efficiently, and economically shorten computing time for high-resolution climate simulations.

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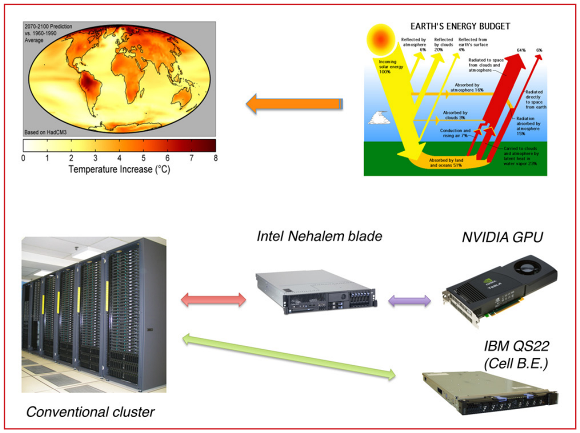

An illustration of accelerated climate simulations. Climate change is closely related to the Earth's "energy budget," including all gains of incoming energy and all losses of outgoing energy. A climate simulation can speed up by offloading the compute-intensive model components from a conventional computer cluster to accelerators such as the Cell Broadband Engine (Cell BE) or NVIDIA graphics processing units (GPUs). *Shujia Zhou, NASA/Goddard*

HECC Application Performance and Productivity

High-End Computing

The Application Performance and Productivity (APP) group of the High-End Computing Capability (HECC) Project at the NASA Advanced Supercomputing facility has three key activities: enhancing performance of high-end computing applications, leveraging software technologies to improve user productivity, and characterizing performance of current and future architectures.

Application optimization efforts this year boosted the performance of several key codes, including: the 3D Hybrid (3DH) Earth magnetosphere simulation code, the Numerical Prediction of Orbital Events (NPOE) code, the AKIE turbomachinery code, and the OVERFLOW computational fluid dynamics code. Extensive code-building and troubleshooting efforts enabled one of the largest 3DH simulations to date, which used 25,000 cores on the Pleiades supercomputer and 40 terabytes of disk space. We also accelerated NPOE simulations by 15 times—enabling generation of critical mission requirements for the Interface Region Imaging Spectrograph (IRIS) spacecraft—and parallelized a version of AKIE using OpenMP, obtaining a nearly 8-fold speed-up. For OVERFLOW, we analyzed and enhanced code performance to scale almost linearly over a large range of cores on all three types of processors on Pleiades.

The APP group regularly characterizes performance of new supercomputing architectures using a suite of NASA-relevant codes, including both benchmarks and full applications. We characterized the performance of several HECC systems based on Intel's Xeon Harpertown, Nehalem, and Westmere processors. We have also investigated several performance-related issues such as contention for shared resources, Hyper-Threading, and hybrid programming for multi-core systems.

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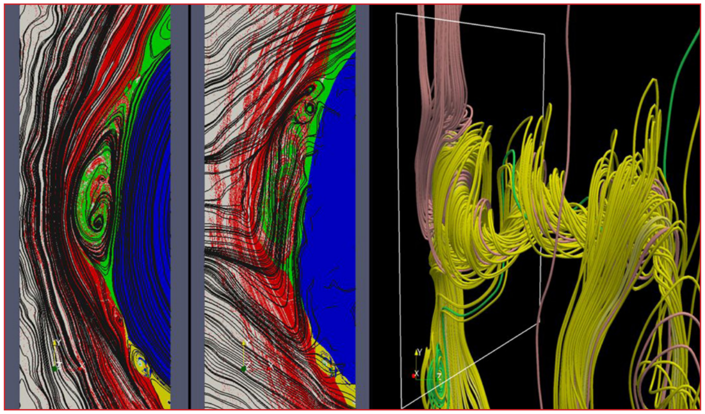

Visualizations from a large-scale simulation of the Earth's magnetosphere enabled by the APP group's 3DH code optimization efforts. *Homa Karimabadi, University of California, San Diego/SciberQuest*

The High-End Computing Capability Project: A Year in Review

High-End Computing

This has been a year of change for the High-End Computing Capability (HECC) Project at the NASA Advanced Supercomputing (NAS) facility. HECC has attained several milestones this year, including delivering over one billion computational hours since the project's inception in 2004, and having a single system pass the 1-petaflop peak performance mark.

Pleiades has quickly become NASA's leading high-end system, surpassing its predecessor, Columbia, in total computational capability delivered to the NASA user community. This year, Pleiades underwent two augmentations that increased its computing capacity by over 170% and brought its peak performance to over a petaflop. The first augmentation added 1,280 Intel Xeon X5570 (Nehalem) processor nodes to support growing analysis needs for Earth sciences. The second phase added 2,304 Intel Xeon X5670 (Westmere) processor nodes supporting all NASA science and engineering projects.

With this newer, more efficient Pleiades system, a large portion of the older Columbia supercomputer was decommissioned this year. Installed in 2004, Columbia was the original supercomputer that established the HECC Project. Although it continued to be highly successful throughout its operation, Columbia had become too expensive to continue operating. The electrical savings alone from the decommissioning paid for the augmentations to Pleiades.

Throughout these considerable changes, HECC has continued to successfully provide all of NASA's mission directorates with the leading-edge systems and computing resources that enable valuable science and engineering advancements.

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Pleiades Westmere-based racks: The addition of the Westmere and Nehalem nodes increased the computing capacity available on Pleiades by 170%. *Dominic Hart, NASA/Ames*

MPI Scaling Using Intel and MVAPICH2

Science Mission Directorate

This work demonstrates some of the complexities that arise when trying to develop software that is meant to run on large-scale supercomputers. It helps the Earth science and high-performance computing communities by identifying system design bottlenecks, as well as performance limitations due to application design.

We undertook a scaling and performance study comparing two implementations of the Message Passing Interface (MPI) software commonly used on high-performance computing (HPC) systems: MVAPICH2 and Intel MPI. The study included running a benchmark developed at the NASA Center for Climate Simulation (NCCS) at Goddard Space Flight Center. The benchmark is representative of the finite-volume cubed-sphere (FVCS) dynamical core, which is part of the GEOS-5 climate modeling system.

This study was designed to evaluate the scalability of the Discover cluster and the FVCS benchmark, while at the same time identifying any performance variability between the MVAPICH2 and Intel MPI implementations.

Results indicate that our benchmark scales very well in a clustered environment. Additionally, we were able to successfully quantify the performance overhead associated with the computational work of the benchmark versus the overhead imposed by each MPI implementation. The benchmark results show that there are indeed scalability problems in Intel's current MPI implementation, with regards to the startup and shutdown of processes, when using a large number of cores (over 1,500).

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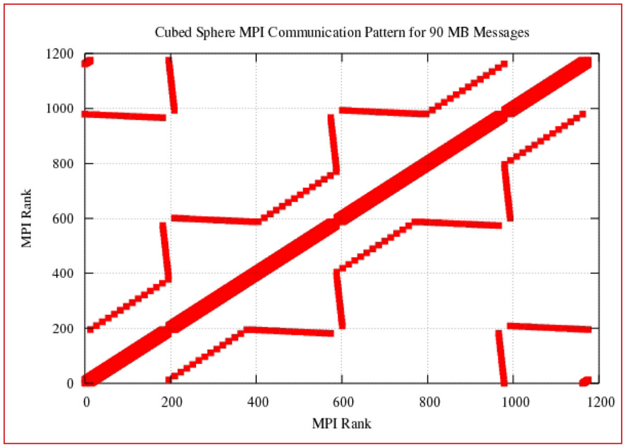

Communication patterns for 90-megabyte (MB) messages of the finite-volume cubed-sphere benchmark on 1,176 processors. *Tyler Simon, NASA/Goddard*

NASA Advanced Supercomputing Archive Environment

High-End Computing

The NASA Advanced Supercomputing (NAS) facility's Pleiades supercomputer has recently been expanded to a peak performance of over one petaflop. This additional computational capability has increased the demands on the archive infrastructure that stores the massive amounts of analysis data generated on the system.

To meet these growing demands, the NAS tape library has been reconfigured to increase the number and rate of tape load/unload cycles possible, improving the speed at which data can be recalled from archive. The tape technology has also been upgraded from the 4th generation of Linear Tape-Open format (LTO-4) to the newest, 5th generation tape (LTO-5). With LTO-5, the tape capacity nearly doubles from 800 gigabytes to 1.5 terabytes per cartridge, and the data transfer rate increases from 120 to 140 megabytes per second. These upgrades have enabled the capacity of the NAS tape library to increase significantly—from 22 petabytes to over 46 petabytes—without having to expand the number of tape slots.

In addition, NAS system engineers are currently evaluating software enhancements, such as enabling data to be transferred directly between the Lustre filesystem and the tape archive. This feature would further increase data transfer rates by bypassing the intermediate step of writing data to a disk cache on the archive server before it can be copied to tape or back to the filesystem.

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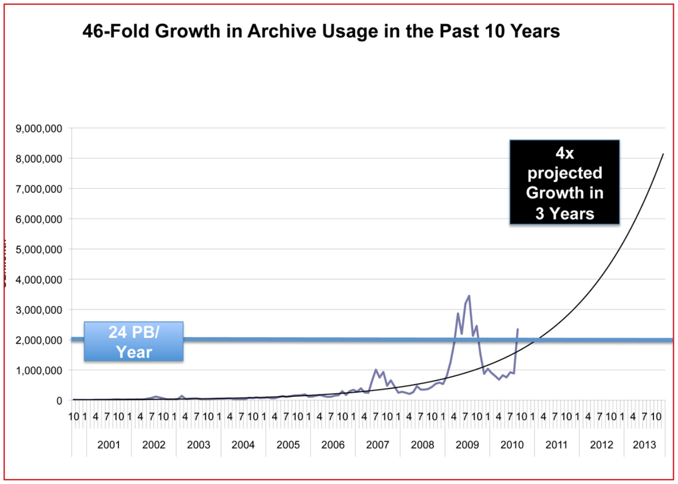

Graph showing the growth in the NASA Advanced Supercomputing facility's archive usage over the past 10 years, and projected future growth trend. *Davin Chan, NASA/Ames*

NASA Center for Climate Simulation Data Services

Science Mission Directorate

The NASA Center for Climate Simulation (NCCS) is using the Integrated Rule-Oriented Data System (iRODS) to develop a comprehensive set of data service capabilities specifically designed for climate research. These capabilities are likely to influence future climate research, while paving the way for new technological advances. NCCS is supporting NASA's participation in the Intergovernmental Panel on Climate Change (IPCC) 5th Assessment Report (AR5), due in 2014. AR5 requirements will be addressed by creating a sustained organizational capacity to handle the IPCC data and future workload.

In addition, services will be created specifically to support NCCS's archive management and data preservation efforts, as well as a range of climate research community requirements. These community research requirements will include distribution of observational data for model validation, integration of high-performance analysis and workflow management tools, and provisioning of cloud resources for broader use in climate research.

Collectively, these activities define a new mission thrust for NCCS—an advanced scientific data services role—that will become an important part of NCCS operations in the coming years.

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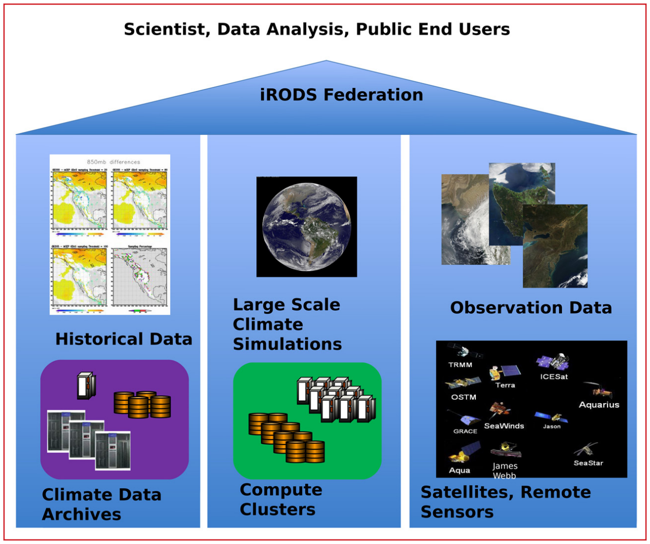


NASA Center for Climate Simulation (NCCS) data services will provide an array of climate research data and applications. *Dan Duffy, NASA/Goddard*

Network Testbed for Enhanced Earth Science Simulations

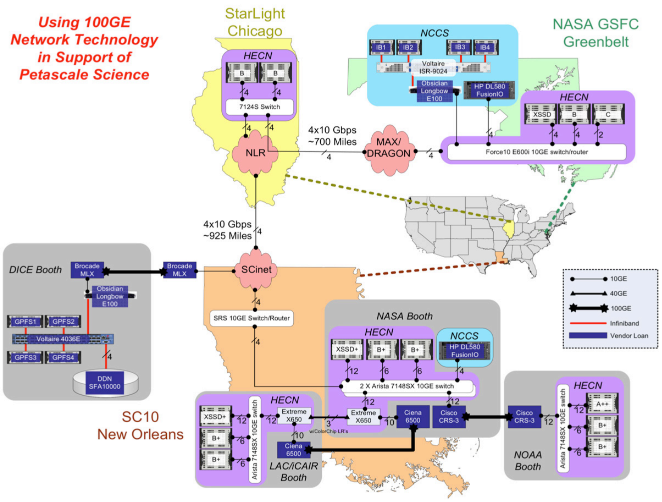
Science Mission Directorate

Using global satellite and remote sensory data, along with NASA's High-End Computing (HEC) capabilities, scientists are developing models to make highly accurate global predictions about Earth's climate. As both model fidelity and the number of remote sensory datasets increase, the amount of data scientists must handle has grown dramatically—some models require more than 120 terabytes per month in wide-area network transfers.

NASA has established a wide-area network testbed to help evaluate high-performance, easy-to-use hardware and software technologies for optimizing data transfer, access, and sharing. The successful outcome of the testbed will allow scientists to focus on their Earth science missions rather than on day-to-day data management tasks.

This testbed connects the NASA Center for Climate Simulation (NCCS) at Goddard Space Flight Center and the StarLight facility in Chicago. At SC10, the testbed has been extended to the research exhibits for the University of Illinois at Chicago's Laboratory for Advanced Computing, the National Oceanic and Atmospheric Administration, and NASA. The testbed involves 10-gigabit-per-second through 100-gigabit-per-second technologies and addresses distance issues through a suite of tests including experimental wire-speed tests, traditional and emerging file transfer applications, and file systems.

The testbed leverages national R&D networks, which enables cost-effective, real-world testing of potential hardware and software solutions for both data access and movement throughout the wide-area network, without impacting operational services.



Major components and partners supporting NCCS high-performance file transfers over wide-area network testbeds and different approaches to 100 gigabit-per-second networking. *Pat Gary, NASA/Goddard*

Pat Gary, Paul Lang, NASA Goddard Space Flight Center
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The Past, Present, and Future of Cluster Computing for Climate Simulations

Science Mission Directorate

The NASA Center for Climate Simulation (NCCS) at Goddard Space Flight Center supplies high-performance computing and data services engineered to support climate simulations within the NASA Science Mission Directorate.

Applications run on the Discover supercomputing cluster contribute to the scientific knowledge of climate change. In addition to running large-scale applications, NCCS also provides a data analysis environment tightly coupled to the Discover cluster for scientists to analyze the large amounts of data generated by their models. Furthermore, Discover is closely linked to a set of web services, including a Data Portal and Earth System Grid Data Node, so that the model data may be shared across the scientific community and with the public.

Over the past five years, NCCS has deployed a scalable cluster approach in order to meet the application requirements for large-scale climate simulations. Recently, NCCS deployed an additional scalable unit consisting of 14,400 Intel Xeon Westmere processor cores and 28.8 terabytes of distributed memory.

This upgrade will provide additional processors to allow NASA's climate models to scale to even greater core counts. It also paves the way for incorporating graphics processing units (GPUs) into the computing cluster over the next year, which will create a prototype next-generation computing environment for NASA climate applications.

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A portion of the Discover cluster located at the NASA Center for Climate Simulation at NASA Goddard Space Flight Center. *Pat Izzo, NASA/Goddard*

Performance Impact of Resource Contention in Multi-Core Systems

High-End Computing

A large percentage of NASA's modeling and simulation work is performed on supercomputing clusters using commodity multi-core processors. While the clusters offer cost-effective peak performance, contention for resources in the memory hierarchy can adversely impact the realized performance. The purpose of our work is to understand how the performance of NASA application codes depends on specific processor architectures.

Resource sharing in commodity multi-core processors, such as the Intel Xeons found in the Pleiades supercomputer at the NASA Advanced Supercomputing facility, can have a significant impact on the performance of production applications. In work done at NASA Ames Research Center, we have used a differential performance analysis methodology to quantify the costs of contention for resources in the memory hierarchy of several multi-core processors used in high-end computers.

In particular, by comparing runs that bind Message Passing Interface (MPI) processes to cores in different patterns, we were able to isolate the effects of resource sharing, and determine that memory bandwidth to a processor socket was the dominant contention factor. This was determined by testing with three benchmarks and four NASA applications on four multi-core platforms.

These results help further our understanding of the specific demands these codes place on their production environments, and each system's ability to deliver performance. This understanding benefits both code optimization efforts and future system procurements.

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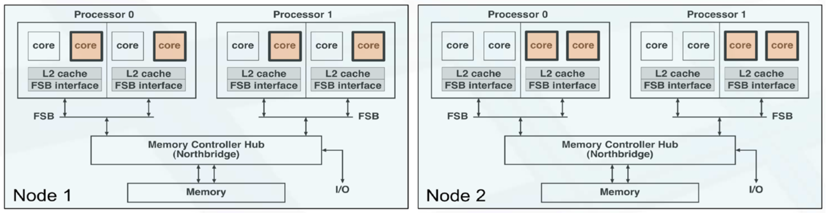

The difference in performance between the two node configurations shown here (where used cores are shown in orange) is due solely to the increased sharing of the L2 cache in Node 2. *Robert Hood, Henry Jin, NASA/Ames*

A Systems Perspective on the Pleiades Cluster

High-End Computing

The Pleiades supercomputer, operated by the NASA Advanced Supercomputing (NAS) Division at Ames Research Center, has a peak floating point performance of over 1 petaflop, making it one of the fastest general-purpose, open-system compute clusters in the world.

Pleiades' dual-plane InfiniBand fabric interconnects the system's 9,472 nodes (84,992 cores) in a partially populated, 11-D hypercube topology. By node count, this represents the largest InfiniBand fabric ever built, requiring over 45 miles of quad and double data rate InfiniBand cabling.

With an aggregate I/O rate of nearly 40 gigabytes per second, Pleiades provides a good balance of sustained data throughput and I/O transactions-per-second capability. The fully connected hypercube system effectively supports workloads of either multiple applications or single, large applications. InfiniBand is also deployed as the primary local area network (LAN) backbone to merge computing, storage, and visualization systems, and to facilitate cross-system data file access. This enables visualization and data analysis to be performed concurrently as applications run, providing very high temporal resolution for viewing NASA's enormous datasets.

The system is operated under a model of continuous operations, with the goal of no system-wide downtime. This provides continuous computational resources to NASA users by making the upgrading of compute nodes and the addition of additional compute racks transparent.

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During 2010, a series of expansions were made to the Pleiades cluster, bringing the system to 84,992 cores and achieving a peak performance of over one petaflop.

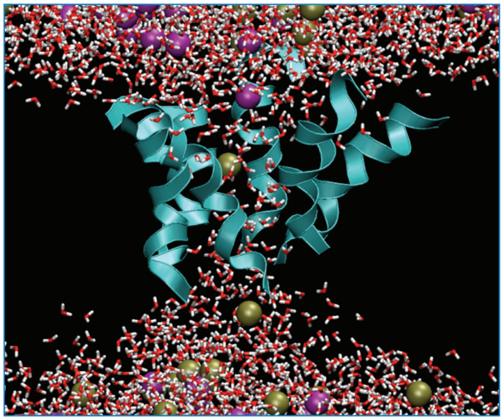
The Universe

Computer Modeling of Protocellular Structure and Functions in the Origins of Life

Science Mission Directorate

The formation of protein channels for transport across membranes was crucial for the emergence of cellular life. In present-day organisms, structurally complex proteins facilitate transport across cell membranes. Early protocellular transport mechanisms must have been simpler, yet with sufficient selectivity and efficiency to support cellular functions. It is likely that cellular membranes and transport mechanisms co-evolved—membranes influenced transport properties, while these properties were conversely constrained by the need to support transport.

We perform molecular dynamics simulations of antiamoebin and trichotoxin ion channels, which are fungal antibiotic peptides that form conducting bundles in membranes. We are investigating the structure, stability, and conductivity of these channels. Results have shown that the channels are stable over long (100 nanosecond) simulations, and that channel pores have radii of 0.30–0.35 nanometers, which allows for transport of almost fully solvated ions with low barriers (6 kilojoules per mole). Computed conductance values agree well with experimental results, and indicate that antiamoebin is a hexamer of 6 molecules, and trichotoxin is a heptamer of 7 molecules.



An antiamoebin ion channel containing six helices (blue) surrounding a water-filled pore (oxygen in red, hydrogen in white). Potassium (gold) and chloride (magenta) are transported via the channel in the presence of an electric field. For clarity, membrane phospholipids are not shown. *Michael Wilson, NASA/Ames*

Simulating membrane systems requires generating long trajectories (100 million steps) for large systems (about 100 thousand atoms). These analyses require large, parallel supercomputers such as Pleiades, and significant data storage. By addressing the evolution of protein structure and function in early cellular life, our work supports NASA's astrobiology research into how life emerged from cosmic and planetary precursors.

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Dust in the Kuiper Belt: How an Alien Might See Our Solar System

Science Mission Directorate

We have modeled the appearance of the Kuiper Belt, the ring of planetesimals and dust beyond the orbit of Neptune, using the NASA Center for Climate Simulation's Discover cluster. Our models will help us understand disk images from NASA's space telescopes, and dust data from NASA's New Horizons mission. For example, the first direct image of an extrasolar planet, made with the Hubble Space Telescope, shows the planet interacting with a ring of dust, just as Neptune sculpts the Kuiper Belt.

Previous models of Kuiper Belt dust ignored collisions among dust grains. Using our own "collisional grooming algorithm," we performed the first 3D, multi-grain-size simulations incorporating grain collisions.

In this simulation, we were able to: track at least 10 times as many particles as previous researchers; model the gravitational perturbations from Jupiter, Saturn, Uranus, and Neptune; and operate on about 16 gigabytes of data simultaneously to model the grain-grain collisions.

We simulated the pattern Neptune makes in the disk and studied how it evolved over time. We imagine that an alien observer could recognize the existence of Neptune—even if the planet were not visible—because of the pattern it makes in the solar system's dust. Our simulation also indicates that our solar system may once have resembled the narrow rings observed around Fomalhaut and other stars.

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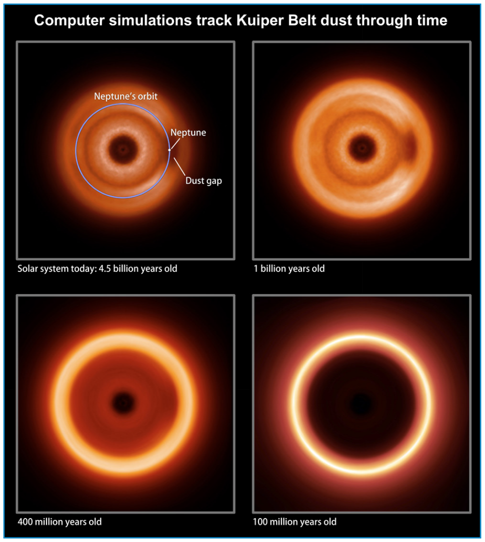

Computer models produced these infrared snapshots of Kuiper Belt dust as seen by a distant observer. By including the effects of grain collisions for the first time, the models show how the appearance of the solar system at infrared wavelengths might have changed over its history. *Marc Kuchner, Christopher Stark, NASA/Goddard*

Dynamic Origins of Solar and Stellar Magnetism

Science Mission Directorate

As the root of solar variability, solar magnetism influences Earth's climate system, regulates space weather, and shapes the geospace environment. Understanding the origins of solar magnetism is a prerequisite to understanding how the Sun interacts with the Earth and the other planets of the solar system, which comprises the core mission of NASA's Heliophysics Division.

NASA missions such as the Solar Dynamics Observatory reveal magnetic activity in the Sun with dramatic clarity. This vibrant magnetism originates below the Sun's surface, in the highly turbulent convection zone where the kinetic energy of plasma motion is converted into magnetic energy in a phenomenon known as a hydromagnetic dynamo.

We are using NASA supercomputing and mass storage resources to model solar and stellar dynamos. Simulations of these dynamos are computationally demanding, requiring high spatial resolution and long time-integrations in order to capture the complex, multi-scale, nonlinear interactions that can give rise to cyclic magnetic activity on time scales that are orders of magnitude longer than those of the convection. NASA's supercomputing resources enable these high-resolution models and accommodate the hundreds of terabytes of data that they generate. The Agency's networking and visualization resources are also essential to properly analyzing this data and maximizing its scientific impact.

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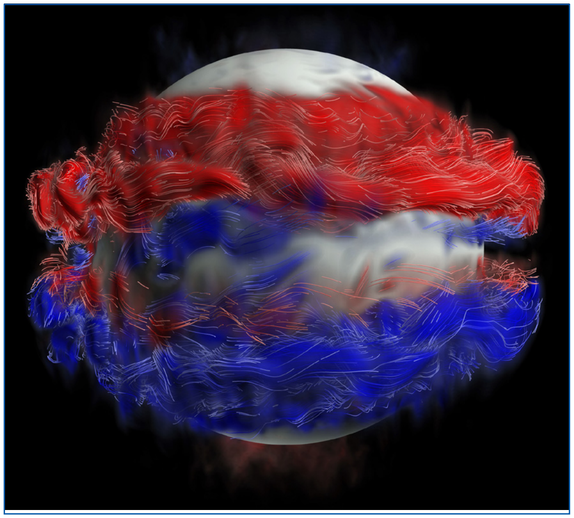

Wreathes of magnetism in a star rotating five times faster than the Sun. Color indicates magnetic polarity, which reverses sign every few years. Observations of young stars confirm that turbulent convection and rapid rotation breed vigorous magnetic activity. *Benjamin Brown, University of Wisconsin; Timothy Sandstrom, NASA/Ames*

Magnetic Fields Emerging through the Solar Convection Zone

Science Mission Directorate

The behavior of magnetic fields near the solar surface is the ultimate driver of Earth's space weather. The goal of this project is to understand the magnetodynamics of the solar surface and upper convection zone in both quiet and active regions of the Sun.

Realistic numerical simulations of solar surface magnetoconvection are needed to model the atmospheric and subsurface behavior of the Sun, interpret observational data, and test and validate observational analysis and inversion procedures.

We compare observables calculated from the simulations with observations from the Swedish 1-m Solar Telescope, the Global Oscillation Network Group (GONG), Hinode, the Solar Dynamics Observatory (SDO) and, later, the Advanced Technology Solar Telescope (ATST), to verify both the simulation results and observational analysis procedures.

Massively parallel supercomputers are essential for running these calculations, which require long time-series on very large grids. These calculations were performed using up to 2,016 cores on NASA's Pleiades supercomputer. Visualization experts at the NASA Advanced Supercomputing (NAS) facility provided a concurrent visualization capability for use with the simulations.

As model building is an integral part of scientific understanding, we are also constructing an exhibit on how scientists use models, in collaboration with the Impression 5 Science Museum in Lansing, Michigan, under a NASA Education and Public Outreach grant. The exhibit will incorporate this work as one of its examples.

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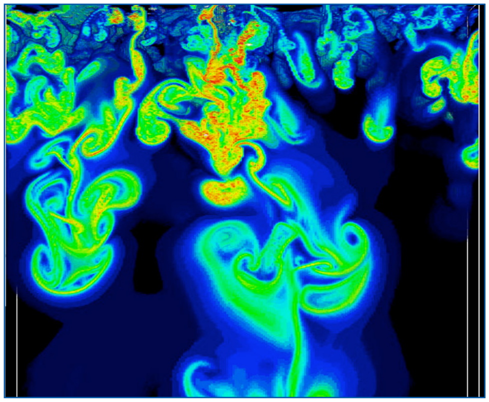

The solar convection zone is very turbulent. This image shows vorticity visualized by the Finite Time Lyapunov Exponent Field for a time interval of 11.75 hours, in a subdomain 21 megameters (Mm) wide x 19 Mm high x 0.5 Mm thick, from a 48-by-48 Mm wide by 20 Mm deep simulation. *Bryan Green, NASA/Ames; Robert Stein, Michigan State University*

New Views of the Solar Atmosphere

Science Mission Directorate

Our research uses advanced, multi-dimensional, radiative magnetohydrodynamic (MHD) simulations to help advance our understanding of how the solar atmosphere is energized and how the solar wind is accelerated. Our work also helps explain the solar drivers of so-called space weather, which can affect the functioning and orbits of satellites and cause damage to electrical grids.

The chromosphere forms a violently dynamic interface between the Sun's surface and outer atmosphere. It is powered by the magnetoconvective energy that drives solar activity and space weather. Our understanding of this crucial region has been severely hampered by the challenging non-local and dynamic nature of the radiative environment.

We use MHD simulations to understand: the role of chromospheric heating and dynamics in the solar atmosphere; mass and energy transfer from the convection zone into the solar corona and solar wind; and the complex interaction of magnetic fields, hydrodynamics and radiation fields. Our results have highlighted the importance of Alfven waves and chromospheric spicules in energy and mass transfer in the solar atmosphere.

This work is part of the science investigation of NASA's Interface Region Imaging Spectrograph (IRIS) small explorer, due for launch in December 2012. Numerical modeling for this work demands supercomputing resources due to the complex radiative transfer and physical processes, and the enormous contrasts of density, temperature, and magnetic field within the interface region. As the physical complexity of simulations increases, so do the processor requirements—ranging from 1–5 million processor-hours per hour of solar time.

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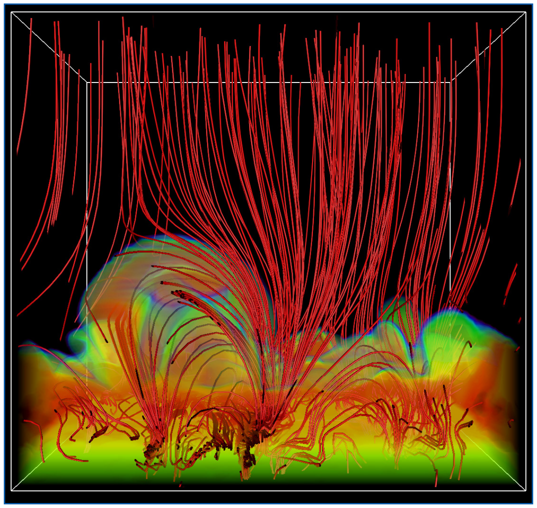

Magnetohydrodynamic (MHD) simulation from the convection zone (bottom), through the transition region (yellow-blue), to the corona. The atmosphere is permeated by magnetic fields (red lines) that sway, carrying enough energy from the convection engine to accelerate the solar wind. *Mats Carlsson, University of Oslo*

Particle Interactions Near Merging Black Hole Binaries

Science Mission Directorate

Our work in simulating the merger of comparable-mass black hole binaries may help deepen our understanding of the large-scale structure of the universe.

As part of this work, we extract the emitted gravitational waves (GW) that may be detected from mergers, and investigate the possibility of simultaneous detection of GW and electromagnetic (EM) signals in the X-ray and gamma-ray bands for certain massive black hole sources.

Our target mission is the proposed NASA–European Space Agency mission LISA, the Laser Interferometer Space Antenna, which will detect GWs from many sources, including massive black hole binary mergers out to redshifts of z ~10. We provide the data necessary for generating the gravitational wave templates that are crucial to determining the parameters of these sources.

Our models simulate black hole mergers by solving the vacuum Einstein equations of General Relativity. The challenge of solving these complex equations is being aided by supercomputer resources at NASA Ames Research Center and NASA Goddard Research Center, which offer long wall-clock times for the large parallel jobs (using 500–1,000 cores) needed for successful binary simulations. Visualization expertise at NASA Ames has enabled us to distinguish between physical and unphysical behaviors in coupled gravity + matter simulations.

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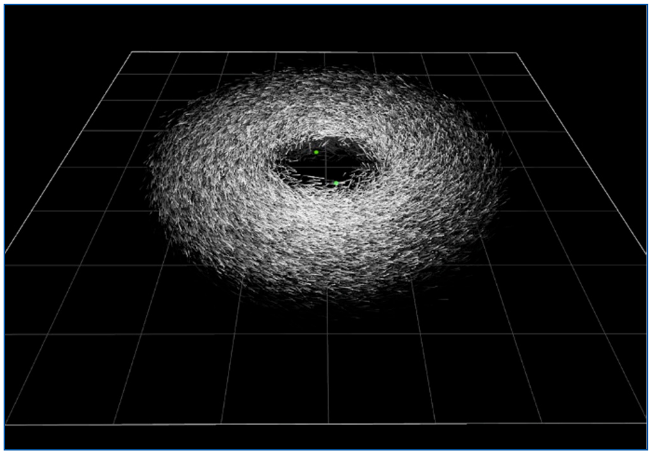


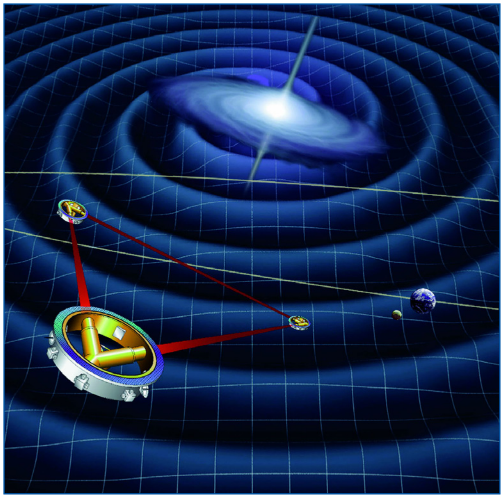
Directional tracks of Keplerian test particles as they begin to move around a merging, spinning black hole binary.
Chris Henze, NASA/Ames

Simulation of Coalescing Binary Neutron Stars

Science Mission Directorate

Researchers at NASA's Jet Propulsion Laboratory (JPL) are are using NASA supercomputers to solve the Einstein field equations, which govern gravitational phenomena. These equations are arguably the most complicated set of nonlinear partial differential equations in classical physics. The wavelengths of the gravitational waves emitted from binary systems are orders of magnitude larger than the objects themselves.

Modern gravitational wave detectors, such as NASA's Laser Interferometer Space Antenna (LISA) and the Laser Interferometer Gravitational-Wave Observatory (LIGO), will require general relativistic simulations of coalescing compact objects (such as neutron stars and black holes) with more accuracy than can be obtained with current state-of-the-art finite difference methods.



LISA, the Laser Interferometer Space Antenna. *Mark Miller, NASA/JPL*

We are using NASA supercomputers to solve the Einstein field equations for binary black hole/neutron star coalescence to enable simulation of the transition from quasi-equilibrium orbits, to tidal disruption and merger, until finally a black hole is formed.

Our newly developed High-Order Shock Capturing scheme converges at 8th order during the inspiral phase for orbiting binary neutron stars. Along with converging at high order for smooth data, the scheme is able to simulate relativistic shocks just as well as traditional high-resolution shock capturing schemes.

"Imaging" the source of gravitaional waves is only possible by matching detected signals with solutions to the Einstein field equations. Analytical techniques are unable to solve the equations in realistic scenarios; only large supercomputers are able to do the job.

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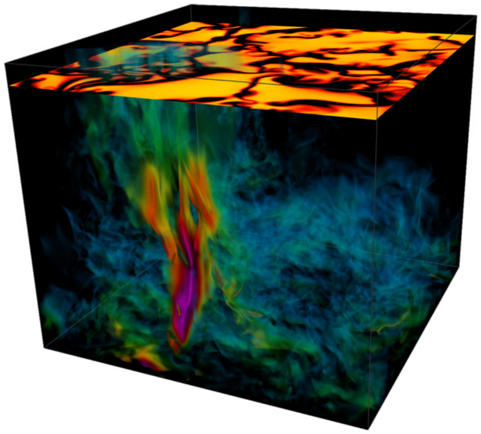
Simulation of Events in the Solar Interior

Science Mission Directorate

The Sun is by far the strongest external influence on Earth's climate, but its output varies over time in complex and poorly understood ways. Understanding the mechanisms that affect solar variation is critical to developing reliable, long-term predictions of climatic conditions and their effects on humanity. Solar variation is also important for assessing spaceflight risks due to space weather phenomena and for studying the evolution of planetary systems throughout the universe. To provide insight into these influential solar variation mechanisms, we are performing large-scale simulations of events in the solar interior, with results validated against space- and ground-based observations.

Fully nonlinear, radiative magnetohydrodynamic (MHD) simulations provide a means to investigate relatively small-scale but important solar phenomena, such as sunspots and other active regions. We have performed simulations of turbulent MHD processes in the Sun's upper connective boundary layer and lower atmosphere, which reveal an intense magnetic field concentration mechanism that may explain sunspot formation. Additionally, our simulations of magnetoacoustic wave propagation provide crucial validation and calibration for inferring conditions and events in the solar interior from helioseismology observations of solar oscillations.



Realistic magnetohydrodynamic (MHD) simulation showing formation of a compact magnetic structure in the Sun's upper convective boundary layer. The image shows magnetic field strength, from 1,000 gauss (black) to 6,000 gauss (magenta), and solar surface temperatures above, from 4,000 Kelvin (black) to 8,000 Kelvin (yellow). *Irina Kitiashvili, Stanford University; Alan Wray, Timothy Sandstrom, NASA/Ames*

Solar simulations such as these must be able to analyze long spans of time at very high spatial resolution, which requires substantial computing and data storage resources. NASA's state-of-the-art supercomputers provide the computational power, speed, and storage capacity needed to support these intensive solar simulation projects.

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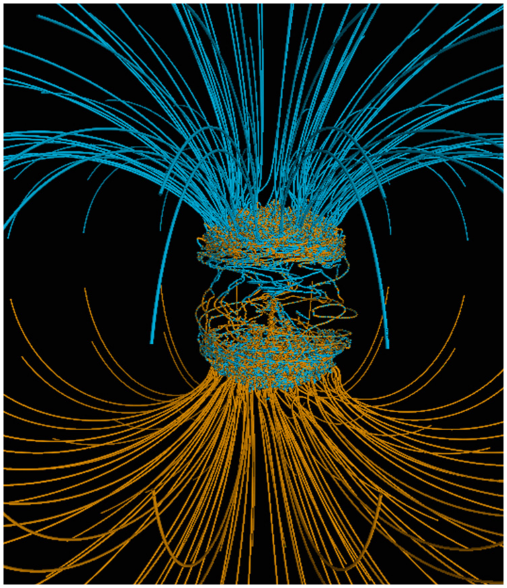
Simulations of Fluid Flows and Magnetic Fields in Giant Planets

Science Mission Directorate

Most people have seen the banded pattern of clouds on the surfaces of giant gas planets such as Jupiter and Saturn, either through telescopes or in NASA mission images. Our simulation research attempts to understand the dynamics within the atmospheres and interiors of these planets and, through comparison of the fundamental fluid dynamics, possibly offer a better understanding of the Earth's atmosphere and oceans.

NASA missions to other planets provide magnificent observations and measurements of their surfaces, and support the Agency's goal to improve our understanding of the solar system's origin and evolution. Using supercomputers, we attempt to explain some of these observations and predict the structure and dynamics in the deep interiors of planets, where observations are not made.



Snapshot of the magnetic field (as magnetic field lines) generated by convection and winds in a simulation of Saturn. Yellow represents outward-directed magnetic field, and blue represents inward-directed field. *Gary A. Glatzmaier, University of California, Santa Cruz*

We use NASA supercomputing resources to simulate the turbulent fluid flows and resulting magnetic fields in our 3D, nonlinear models of gas giants. These systems are programmed to solve for the fluid velocity, magnetic field, and thermodynamic variables throughout our model planet for the tens of millions of time steps required to simulate the magnetohydrodynamics. A typical simulation needs to run for more than a year on hundreds of processors. The resulting data is then analyzed and illustrated in images and movies.

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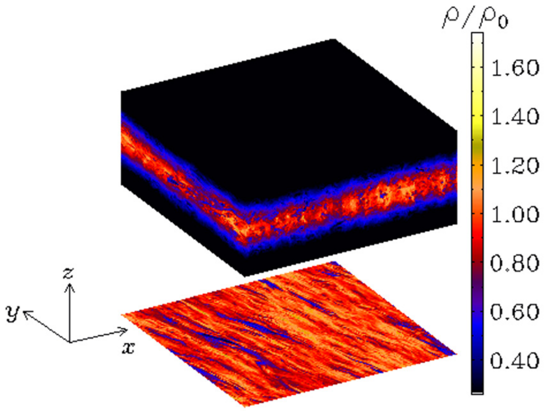
Simulation of Hydromagnetic Turbulence and Planet Migration

Science Mission Directorate

Extrasolar planets are a major focus of NASA missions. In recent years, their detection has become routine, and the number of observed planetary systems is now significant enough that they can be used to constrain theoretical models. Our models explore in detail one of the major processes that may occur in the course of planet formation, enabling further comparison between theories and observations.

The circumstellar gaseous disk around a young stellar object plays a crucial role in the formation and migration of planets. The disk is generally believed to be turbulent, most likely due to the presence of a weak magnetic field. The gravitational influence of the density fluctuations of this turbulent gas makes the planetary objects therein undergo "random walks."



Snapshot of the gas density in a local region of a turbulent circumstellar disk. The x, y, and z axes indicate radial, azimuthal, and vertical directions, respectively. The bottom plane shows the slice along the disk mid-plane. *Chao-Chin Yang, University of California, Santa Cruz/American Museum of Natural History*

The magnitude of this effect has many important consequences for our current understanding of planet formation scenarios. We use the Pencil Code, a parallelized, cache-efficient, high-order finite-difference code capable of solving magnetohydrodynamics equations as well as calculating the movement of particles.

Using a statistical approach, we can accurately quantify the evolution of the orbital properties of these particles with time. This measurement has provided us with further insight into the life of extrasolar planets and our own solar system.

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Ultra-High-Resolution Galaxy Formation

Science Mission Directorate

Continuing our long-term work in understanding how the first stars and galaxies formed, we have achieved unprecedented high-resolution (3 parsec) cosmological simulations. These self-consistent simulations resolve—for the first time—star formations in a large cosmological volume.

In our simulations, feedback from star formations is properly treated, because the Sedov and subsequent phases of the evolution of supernova remnants are adequately resolved. The simulations produce galactic winds driven by supernovae in a fashion similar to what is observed, strongly validating the physical realm of the simulations.

Characteristics of the simulated galaxies help to interpret how they changed over time into the objects recognized in the present universe. Our work will also help to understand future observations of the most distant galaxies, in support of NASA's James Webb Space Telescope, a large, infrared-optimized space telescope scheduled for launch in 2014.

NASA's Pleiades and Columbia supercomputers enable our very large simulations, which would otherwise not be possible. Visualizations of the simulation data, provided by experts at the NASA Advanced Supercomputing (NAS) facility, help us interpret and understand the data.

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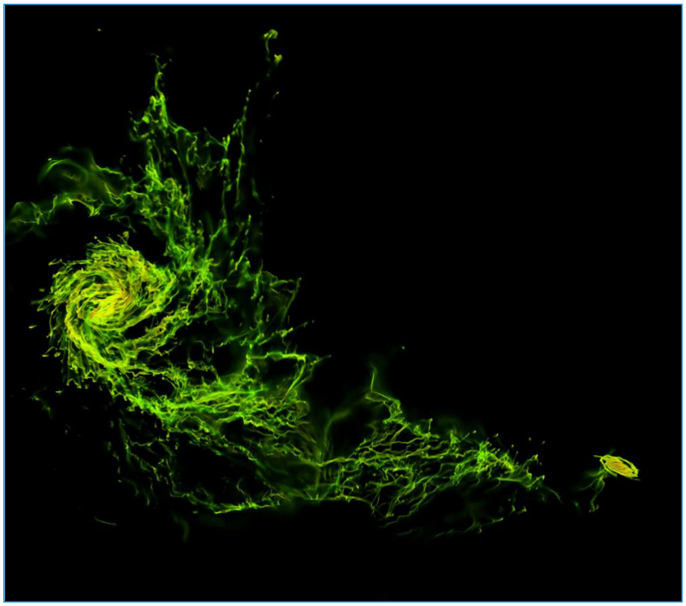

This image shows two galaxies in the process of merging, and how gas accretes onto galaxies through complex, spiral-arm-like streams. The smaller galaxy at lower right just had a close passage around the larger galaxy.
Su Simon, Princeton University

Understanding the Nature of Dark Matter Halo Mergers in Galaxy Formation

Science Mission Directorate

The material in the universe is dominated by dark matter that can only be detected through its gravitational wave signature on the vast range of astrophysical scales. Over the years, scientists have been able to create simulations of how miniscule density fluctuations of dark matter may evolve in an expanding universe. From such simulations, we have found that entire galaxies can materialize from these tiny density fluctuations, which form the cosmic scaffolding on which dark matter accumulates.

This project explores how Milky-Way-sized dark matter halos merge and evolve over cosmic time. Using two sophisticated codes, GASOLINE and GADGET2, the initial condition settings in the simulations are predetermined to result in the target halo sizes. We simulate numerous histories of dark matter mergers, in which two or more comparably sized dark matter halos merge and grow over cosmic time. The simulations produced are "cosmologically correct" scenarios that include the evolving structure and distribution of the ever-expanding dark matter, the behavior of gases, and star formation.

The supercomputing and visualisation facility at NASA's Jet Propulsion Laboratory enables us to meet the enormous numerical challenges in performing and analyzing these state-of-the-art simulations. Our simulation results can be compared with observations of actual galaxies obtained from NASA's Hubble, Spitzer, and WISE space telescope data.

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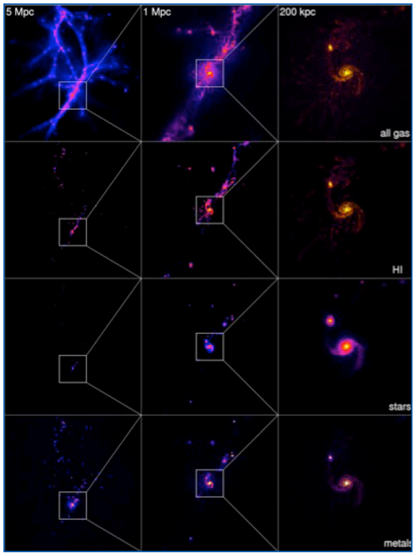


Image from a simulation showing the structure of a galaxy halo the size of the Milky Way, and the contents within it. Columns (from left to right) correspond to simulation box-sizes of 5 megaparsecs (Mpc), 1Mpc, and 200 kiloparsecs. Rows (from top to bottom) correspond to "all gas," all of the neutral hydrogen ("HI"), the distribution of all the stars, and gaseous elements heavier than helium. *Leonidas Moustakas, Kyle Stewart, NASA/JPL*

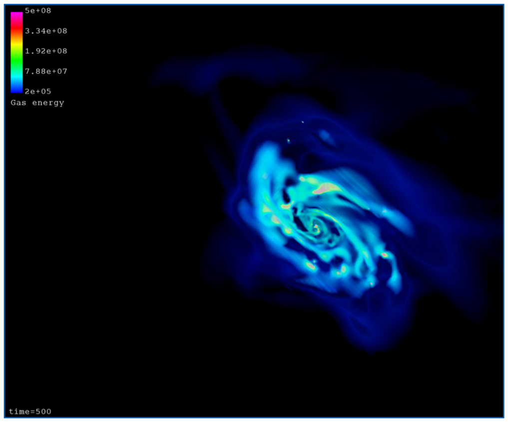
Visualizing Simulations of Cosmology and Galaxy Formation

Science Mission Directorate

According to the now-standard Lambda Cold Dark Matter (Lambda CDM) “double dark” theory, 95 percent of the universe’s density is invisible dark matter and dark energy. Only 5 percent is ordinary matter, and about a tenth of that is the visible stars and gas in galaxies.

As part of the key challenge in astronomy to explain how the structures in today’s universe formed within the Lambda CMD framework, our team is working to understand both the structure and distribution of dark matter halos, and the formation and evolution of galaxies within the dark matter cosmic web.

We are producing simulations of large volumes of the universe at resolutions high enough to follow the formation and evolution of all the dark matter halos that can host galaxies, including the merging of these halos. The halo merger trees form the basis for semi-analytic models (SAMs) that can follow the evolution of the entire population of galaxies.



Visualization of the cosmic web: an image, one billion light years across, of the final snapshot from the 8-billion-particle Bolshoi simulation, made with the Adaptive Refinement Tree (ART) code. *Anatoly Klypin, New Mexico State University; Stefan Gottloeber, AIP-Germany*

The Pleiades supercomputer at the NASA Advanced Supercomputing (NAS) facility has enabled us to run dissipationless and hydrodynamic simulations, in particular, our Bolshoi Gigalight-year simulations. Collaboration with NAS visualization experts has been crucial for visualizing and interpreting the results of these simulations to understand the evolving cosmos.

We have published results from a pilot project using new NVIDIA graphics processing units (GPUs) to greatly speed up parts of our radiative transfer calculations.

Joel Primack, Nina McCurdy, University of California, Santa Cruz
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NASA SC10 SESSIONS

Wednesday, November 17th

User Experiences with SGI Altix UV
Birds-of-a-Feather
12:15 p.m. – 1: 15 p.m.
Room 282

SGI's new Altix UV is a unique and exciting platform for large-scale, shared-memory computing. This BOF will bring together many of the early adopters of this technology to share results, programming and operating experiences, and plans for future projects. Participants will include an array of users from research and commercial organizations, and cover many interesting use-cases for shared memory, such as large-scale data and image analysis, and complex systems simulation. Panelists include: Sean Ahern, Director of the University of Tennessee Center for Remote Data Analysis and Visualization; Dr. Rune Linding, Cellular & Molecular Logic Team Leader, The Institute of Cancer Research; Michael Pflugmacher, Assistant Director of High End Computing, National Center for Supercomputing Applications; Nick Nystrom, Director of Strategic Applications, Pittsburgh Supercomputing Center. This BOF is hosted by the SGI World-wide User Group, a volunteer-run organization for and by users of SGI's products and services.

Session Leaders: Gabe Turner (Primary Session Leader) - University of Minnesota;
Davin Chan (Secondary Session Leader) - NASA Ames Research Center

Providing a Universal Performance Measurement Framework for GPCPU
Birds-of-a-Feather
5:30 p.m. – 7:00 p.m.
Room 393

With the advent of General Purpose CPU (GPGPU) and Cloud Computing, current measures of large-scale systems performance (e.g., Top500) are becoming less useful at providing insight into systems performance and performance trending, and ignore the emergence of Cloud Computing. The science and engineering communities that rely on GPCPU computing need a more reliable standard of measure. This has the potential to increase competition, leverage new technologies like Cloud Computing, reduce purchasing overhead, and increase the use of scientific computing. Problems to overcome are issues such as the lack of adoption, relevance to real-world performance, and completeness of the historical record. Further, the number and quality of submissions are often hindered by issues such as practical time constraints, investment of staff resources to run benchmarks, physical access to a system, or willingness to participate.

This BOF will discuss alternative methods of ranking for large-scale systems, which might leverage existing measures including the Top500, SPEC, the NAS Parallel Benchmarks, etc. The ultimate goal is to provide a relevant, timely, and more universally adopted measure of systems performance for chip and system designers, system integrators, system providers, cloud providers and end users. Panel members include representatives from Amazon, Argonne, IBM, Intel, NASA, SGI, and SPEC. Participants will make a presentation that may discuss proposed measures, issues with current measures, or other relevant information. An open group discussion will follow.

Session Leaders: Bob Ciotti (Primary Session Leader) - NASA Ames Research Center; Davin Chan (Secondary Session Leader) - NASA Ames Research Center, Computer Sciences Corporation

Thursday, November 18th

Pushing the Frontiers of Climate and Weather Models: High-Performance Computing, Numerical Techniques and Physical Consistency
Panel Session
3:30 p.m. – 5:00 p.m.
Room 384–385

The climate and numerical weather prediction community has worked feverishly over the last several decades to successfully port atmospheric models to high-performance computers. The emergence of new, massively parallel architectures incorporating multi-core/many-core processors is yet another challenge. The community is taking on this challenge aggressively by revising and optimizing existing algorithms, proposing new numerical techniques, and employing innovative semi-structured grids to describe the Earth's atmosphere. Our panelists are all accomplished in the leading edge of modeling on high-performance computers. They will present and discuss the variety of techniques used and being developed today for the latest parallel architectures, analyze the numerical issues which result from the need to attain high-performance, and will shed light on the future of climate modeling and numerical weather prediction. The session will end with questions from the audience to the panel.

Panelist Details: Christiane Jablonowski (Moderator) - University of Michigan; David Randall - Colorado State University; Terry Davies - UK Meteorological Office; William Putman - NASA Goddard Space Flight Center; Shian-Jiann Lin - Geophysical Fluid Dynamics Laboratory; Peter Lauritzen - National Center for Atmospheric Research

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